



**University of
Zurich**^{UZH}

**Zurich Open Repository and
Archive**

University of Zurich
University Library
Strickhofstrasse 39
CH-8057 Zurich
www.zora.uzh.ch

Year: 2015

EEG of two persons during their roles as spiritual trance healer and as client – a pilot study

Faber, Pascal L ; Milz, Patricia ; Lehmann, D

Abstract: Two experienced spiritual (trance) healers who occasionally treat each other were recorded simultaneously, each with 27 EEG channels. The participants alternated their roles as healer and client (8 runs of 15 min: each 4 times healer, 4 times client). FFT spectral analysis was done using average reference. Spectra were averaged across the 27 channels. Power was integrated for each of the eight frequency bands (delta through gamma). The eight simultaneous results of the healing runs (client vs healer condition) were statistically compared (frequency band-wise ANOVA). In their role as healer compared to their role as client, both participants showed less power in the function-inhibiting delta and function-facilitating beta-3 EEG frequency bands. In sum, this pilot study of spiritual (trance) healing found distinct EEG states (common to both participants) that combined EEG characteristics of functional inhibition and functional facilitation in healer and client which cannot be reduced to changes in drowsiness or alertness.

Posted at the Zurich Open Repository and Archive, University of Zurich

ZORA URL: <https://doi.org/10.5167/uzh-118101>

Journal Article

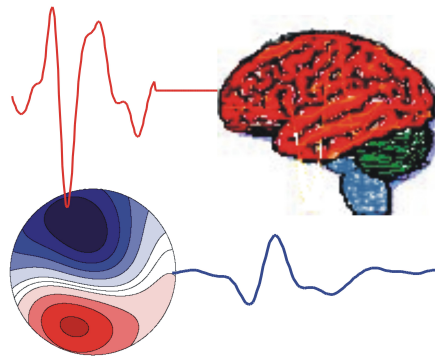
Published Version

Originally published at:

Faber, Pascal L; Milz, Patricia; Lehmann, D (2015). EEG of two persons during their roles as spiritual trance healer and as client – a pilot study. *Kognitive Neuropsychologie des Menschen - Human cognitive neurophysiology*, 8(1):23-29.

KOGNITIVE NEUROPHYSIOLOGIE DES MENSCHEN

HUMAN COGNITIVE NEUROPHYSIOLOGY



Impressum

Herausgeber: Wolfgang Skrandies

© 2015 W. Skrandies, Aulweg 129, D-35392 Giessen
wolfgang.skrandies@physiologie.med.uni-giessen.de

Editorial Board:

M. Doppelmayr, Mainz

A. Fallgatter, Tübingen

T. Koenig, Bern

H. Witte, Jena

ISSN 1867-576X

Editorial

This issue is dedicated to Professor Dr. Dietrich Lehmann (1929–2014) who passed away in June 2014 at the age of 84. He is known to the "EEG world" as a pioneer of brain mapping and topographic analysis, as well as for his work in the fields of cognitive neuroscience and psychophysiology.

The papers presented here are a mix of personal memories and data papers on electrical brain activity that is recorded in order to elucidate cognitive processes. In the fall of 2014 a number of former colleagues of Dietrich Lehmann as well as guests at the Zurich laboratory were invited to submit a contribution. There was no special format requested; it could be a conventional data paper, a scientific review, or a personal account about topics of scientific collaboration.

We finally are able to present five contributions that illustrate the width of Dietrich Lehmann's scientific interests, ranging from basic neurophysiology to higher cognitive brain processes.

Wolfgang Skrandies

Kognitive Neuropsychologie des Menschen wurde im Jahr 2008 gegründet. Hier sollen wissenschaftliche Artikel zu Themen der kognitiven Neuropsychologie des Menschen erscheinen. Sowohl Beiträge über Methoden als auch Ergebnisse der Grundlagen- und klinischen Forschung werden akzeptiert. Jedes Manuskript wird von 3 unabhängigen Gutachtern beurteilt und so rasch wie möglich publiziert werden.

Die Zeitschrift ist ein elektronisches "Open Access"-Journal, ohne kommerzielle Interessen; <http://geb.uni-giessen.de/geb/volltexte/2008/6504/>.

Eine dauerhafte Präsenz der Zeitschrift im Internet wird durch die Universität Giessen gewährleistet.

Human Cognitive Neuropsychology was founded in 2008. This journal will publish contributions on methodological advances as well as results from basic and applied research on cognitive neuropsychology. Both, German and English manuscripts will be accepted. Each manuscript will be reviewed by three independent referees.

This is an electronic "Open Access"-Journal with no commercial interest, published at <http://geb.uni-giessen.de/geb/volltexte/2008/6504/>.

Online presence is guaranteed by the University of Giessen.

Instructions for Authors

Only original and unpublished work will be considered for publication unless it is explicitly stated that the topic is a review. All manuscripts will be peer-reviewed. Both German and English versions are acceptable. After publication, the copyright will be with the editor of the journal. Usage of published material for review papers will be granted. Manuscripts (as WORD or TEX files) should be sent to wolfgang.skrandies@physiologie.med.uni-giessen.de.

Organization of manuscripts: The title page with a concise title should give the authors' names, address(es), and e-mail address of the corresponding author. The manuscript should include an abstract in English (maximum 300 words). Organize your work in the sections *Introduction*, *Methods*, *Results*, *Discussion*, and *References*. Please also supply a short list of keywords that may help to find your publication.

Illustrations: All figures should be submitted as png or Coreldraw files. Please supply figure legends that explain the content of the figures in detail. Since this is an electronic journal color figures will be published free-of-charge.

The *Literature* should only include papers that have been published or accepted for publication. The reference list should be in alphabetical order by author. In the text, references should be cited by author(s) and year (e.g. Johnson, Hsiao, & Twombly, 1995; Pascual-Marqui, Michel, & Lehmann, 1994; Zani & Proverbio, 2002).

Examples of reference format:

- Johnson, K., Hsiao, S., & Twombly, L. (1995). Neural mechanisms of tactile form recognition. In M. Gazzaniga (Ed.), *The Cognitive Neurosciences* (p. 253-267). Cambridge, Mass.: MIT Press.
- Pascual-Marqui, R., Michel, C., & Lehmann, D. (1994). Low resolution electromagnetic tomography: a new method for localizing electrical activity in the brain. *International Journal of Psychophysiology*, 18, 49-65.
- Zani, A., & Proverbio, A. (Eds.). (2002). *The Cognitive Electrophysiology of Mind and Brain*. San Diego: Elsevier.

Contents

J. Wackermann — Dietrich Lehmann – A personal recollection	1
H. Witte — Dietrich Lehmann – Doctor honoris causa of the Friedrich Schiller University Jena	8
W. Skrandies — Dietrich Lehmann as a Neurophysiologist	18
P. L. Faber, P. Milz, D. Lehmann — EEG of two persons during their roles as spiritual trance healer and as client – a pilot study	23
M. Koukkou — EEG manifested brain functional states with state-dependent information processing: a short review of the concept from the sixties to today	30
W. Skrandies — Abstracts of the 23 rd German EEG/EP Mapping Meeting	36
Announcements — Ankündigungen	52

Dietrich Lehmann – A personal recollection

JIŘÍ WACKERMANN

Independent researcher

Gutach im Breisgau, D-79261 Germany

eMail: mail@jiri-wackermann.eu

If I had to tell, as briefly as possible, who Dietrich Lehmann was as I knew him, I would say, he was a living instance of the unity of life-in-science and life-for-science. This may sound like a rather formal and somewhat abstract characteristic; but I believe it was precisely this unity that made him the unique and fascinating personality he was. In the few paragraphs that follow I hope to make this characteristic more concrete, more vivid by sharing a few personal rememberings.

Perhaps I should add that I was not Dietrich's disciple, neither formally nor factually; I never considered myself as being part of the 'Zurich school'. We met at some research topics of shared interest and worked together for a while, that's all. We had periods of intensive exchange, followed by periods of detachment and silence. Our acquaintance endured some twenty-five years: certainly a significant period in one's biography, and yet too short to grasp one's personality in his entirety. I'm saying this to make clear that I'll not try to sketch a full portrait of Dietrich Lehmann, neither as academician nor as a private person; may others, who were closer to him and knew him for a longer period of time, take up this task. As I said, we met and worked together, that's it. But already the very first encounter was quite different from usual academic contacts, truly unconventional. It was at a conference titled 'Mathematical approaches to brain functioning diagnos-

tics', organized by Ivan Dvořák and Arun Holden in Prague, September 1990. During a coffee break, Dietrich Lehmann stopped at the stand where I was demonstrating a program displaying EEG field maps. He asked a few questions; in a minute we were deeply in a discussion concerning measures of similarity between maps; and alas! only a few minutes later we were involved in a vigorous debate! The next session was about to start and he disappeared as abruptly as he showed up, leaving me unhappy for the rest of the day. Now I had a unique opportunity to present a piece of my work to an undoubtedly high authority in the field, and I missed my chance. Indeed, in the academic culture of that country and those times, it was undesirable and really unwise (to say the least) to oppose an authority so explicitly as I did. Hierarchy, degrees and ranks were important and had to be observed. So I felt not only that by lack of diplomacy I had lost my chance on that day; surely I had destroyed all my chances to have any further exchange with him! The next day I happened to meet Dietrich Lehmann in the lobby. He looked at me and asked, a little bit reservedly but by no means unfriendly, and (so it seemed to me) with a spark of amusement in his eyes: "What now—shall we continue our discussion?"

This was thus my first experience with Dietrich: he was neither upset by my violation of academic conventions, nor horrified by my lack of good

manners—no, against all expectations, he seemed to enjoy the whole situation. That time we managed to finish our discussion peacefully, even if not in a complete agreement. Then he asked me briefly a few questions about my present position and prospects, and left. At that moment I couldn't know that soon I'd have to learn more about this spark of ironic amusement in his eyes. To my great surprise, a few months later he called me on the phone and offered me a post-doctoral position in his workgroup in Zurich. I accepted immediately—a step that made a major change in my life.

I arrived at Zurich one day of March 1991, quite late, equipped with a minimum of personal things, a few books—a thick handbook of applied mathematics among them—and no clear idea of what I was going for. No expectations, that was right. Soon I had to learn that expectations, positive or negative, never worked with Dietrich; he with his mercury-like motility was beyond all expectations, truly unpredictable.

It was quite a surprise that Dietrich himself was awaiting me at the Zurich main station. (In all academic institutions I was affiliated with before, the picking-up order for guests and visitors was defined as precisely as the intra-institutional pecking order. It was simply inconceivable that a professor and head of department would go to pick-up an unimportant post-doc.) It was a forceful capture: he drove me to the hotel, suggested a brief visit to the lab rooms in the neurology hospital at Haldenbach, and gave me a few minutes to refresh—entirely ignoring the fact that I had spent twelve hours on the rails and wished for a substantial recovery. He brought me to the lab, showed me quickly the rooms, and then invited me for a late dinner in a pizzeria nearby. There he asked me a lot of questions about the neurophys-

iology community in Czechoslovakia, about some persons I knew and also a few persons I couldn't have known at all. I'm afraid my vague responses were not always meeting his expectations. Finally he left me, as I was tired almost to death, wishing me good-night with a friendly smile.

So he was, Dietrich, as I had to learn to know him in the months that followed: always focused on the matter of his interest, fully dedicated to his research, passionate for research, wishing to know and know more. In one word: there was immense *intensity* in his approaching everything, whether research matters or trivia of everyday life. The latter distinction is unimportant, anyway; for Dietrich's life was doing science, and more: truly *making* science.

Now, this was new and really exciting. There was an opportunity—nay, a privilege—not only to work in Dietrich's group and under his guidance but also to participate in a field of research that he, Dietrich, had opened himself and that was still in continued development: topographic analysis of brain electrical fields, and particularly the study of brain activity in terms of functional microstates: his invention, his creation, his most important and permanent contribution to neurophysiology.

Let me point out that I'm referring to times more than twenty years ago: the methodology of the new field was still *in statu nascendi*, there were partly complementary, partly competing approaches, methods were still under development, computational power was limited. The working conditions of those days were somehow spartan compared to those of the present days—one can't say things were better or worse: just different. Also, the field was new and the novel approaches too unusual for the most of the EEG community, so there was a considerable resistance to ex-

pect and to overcome. At any rate, there was a pioneering spirit, dedication and enthusiasm, at which I'm still looking back with a bit of nostalgia.

Dietrich, of course, was in the centre of all things: *spiritus agens*, cautious mentor, severe critic, friendly colleague—and sometimes a sort of playing child. This variety of appearances was something natural in him; he was not playing rôles, so he was not 'changing rôles' either; he was all that in one person. If he was not truly omnipresent, he was very close to that. He could appear in the lab any time, and so he did, commented, criticized, asked questions—even questions which, as I believed, we already had discussed and finished another day. This was something I had to learn soon about Dietrich: for him nothing has ever been 'marked as done'; there were no definitive answers, no patent solutions. Everything—or almost everything—was open to continuous examination, discussion, questioning: results, conclusions, presentation strategies as well as commonly accepted assumptions, established principles, or dogmas.

Discussions with Dietrich were just unforgettable. He was always precisely focused, always aiming at the target (significantly, his birth-sign was Sagittarius), although this wouldn't prevent him from changing the target several times during a debate. Everything was sharp in his expression: sharp look of his eyes, often seconded by his sharp tongue, and time and again aided by a sharp pencil in his hand. Every one who had ever worked with Dietrich was impressed by his drawing skills and his ability to illustrate his arguments by those little pictures and sketches.

We had to have many discussions, on diverse topics, in diverse settings: at my workplace in the lab, in the cafeteria of the university hospital, or

elsewhere in a café or a pizzeria outside. Dietrich was quite inventive in finding places to talk; once he suggested to have a drink in the lobby of the Hotel Dolder, one of the most expensive places in the town—"just to see how those wealthy people are doing", as he put it. We had a sip of beer from small glasses (very *chic*, indeed!), Dietrich dropped a few sarcastic comments, and then he drove us back to Haldenbach where we returned to less profane things—that is, data and methods.

As our work progressed, our discussions turned from technical and procedural issues toward conceptual questions; that is, we were entering the difficult terrain of *theory*. Why so difficult?

Dietrich was no friend of extensive theorizing, to say the least. Once he observed in a panel discussion (Başar & Schürmann, 1997): "Unfortunately, the EEG world has few trained physicists—but many EEG theoreticians." This was said in the context of the EEG vs. MEG competition debate (an issue probably largely forgotten by now) but Dietrich's statements were of more general nature: "I think the name of the game is—in science—to come to conclusions about the nature of the data [...] The less theory, the better it will be. At the end there needs to be a lot of facts and few theories." In other words, the facts were for him the very matter of science, whereas the theory was at best a supplementary construction. But what makes a cluster of data a proven fact? "We need more data" was Dietrich's response whenever we were facing puzzling, counter-intuitive, or erratic results. Once I asked him why should we expect more data to bring more clarity if we were unable to make a clear picture out of these data here?! Dietrich remained unimpressed by my provocations: "We need more data, that's it!" On the other hand, there were moments where he himself uttered skeptically, "more data, more

noise!” Were these moments of real doubts, or was it only his special sort of humour? I was never sure.

Dietrich’s view of science was expressly empiricist; it was, in fact, an *extreme empiricism* of a sort of Claude Bernard’s celebrated *Introduction*: focus on facts, and facts again; readiness to accept results of observation or experiment, regardless how unexpected, unforeseen, unlikely they may seem; and an aversion against all preconceived ideas or ‘theories’ that may mold and distort experimental results. Briefly, Dietrich believed in a theory-free experiment. But what was a ‘theory’ in a positive sense of the word, cleaned from negative connotations such as preconceived ideas and biases? This was not quite clear.

Dietrich frequently emphasized the need for ‘data-driven’ research strategies, in contrast to ‘concept-driven’ or ‘theory-driven’ approaches. But I had to ask myself, and him, where is the demarkation line between those two domains, and how is it defined if not by theory, or our understanding of theory? Even if a theory-free experiment was possible, the data required a theory-based interpretation. These were pertinent questions especially for the field of microstate analysis: the notion of state of a system, generally, and the concept of *functional state* of the brain, particularly, were primary elements of a (proto-)theory, and only this theory made the interpretation of brain electrical data in terms of brain functional microstates possible at all. Dietrich’s famous dictum, “one brain and one mind at one moment in time,” (Başar & Schürmann, 1997, p. 467) seemed a self-evident truth—what else was it if not a foundational assertion, that is, an axiom for a theory?

We touched these issues again and again in our conversations; these were the most lively debates

we ever had. Of course, I was not a novice to experimental research, I had already passed my formative years, I had my own views of things, and so had Dietrich, too. As far as we were discussing procedural issues, statistics and such, we could arrive after a shorter or longer discussion at an agreement (even if only provisional). Things became more delicate as we were approaching the foundational problems, and both parties had to find their words and to construct their arguments on the fly; rational argumentation was not rarely mixed with metaphors and figurative examples.

I’ve mentioned Dietrich’s passion for questioning almost everything; but the fact is that his readiness for questioning dogmas had its limits. (Admittedly, I’m touching a sensitive issue now; but if honesty is a sign of a true friendship, I think I can do so without fear of being misunderstood.) When he was convinced about *his truth*, he wouldn’t deviate any little bit from his position, and then he could be pretty much dogmatic: “How else could we think of it?” I had never doubted that in these moments he was *not* driven by self-overestimation or academic vanity. Surely he believed that he was just doing his service to truth, and he did so with all his habitual intensity and sharpness. After some time I learned that it was often wise to change the topic timely, but again and again I failed to do so; diplomacy was never my strong point, as proven by the story of our first encounter in Prague. Well, this was my fault: at the end of such debates I was often feeling like a cat overrun by a steam-roller.

So what were we doing there—philosophy? In a sense, yes: I mean a working scientist’s philosophy, a totality of one’s views, thought habits and intuitions, an expression of the unity of intellect and temperament. I was never much interested in that specialized branch of research and teach-

ing practiced at universities as ‘philosophy of science’. Dietrich, by contrast, had some favorite authors in the field of philosophy of science, but I never understood whether these were deeper influences or merely sources of handy quotations. He occasionally mentioned Mario Bunge, Argentinian philosopher of a monist/materialist sort, a prolific author by whom I’ve never read a single line. Dietrich didn’t like talking about ‘understanding’ in science; for him this was an empty word, science in his view was “nothing but a collection of facts between which we established convincing correlations,” and then he used to quote Bunge: “what does it mean, understanding [for example] what speed is? and what’s the difference from understanding consciousness?” But this was more about Dietrich’s *blitzkrieg* argumentation style than about Bunge’s philosophy. — On quite a different line, Dietrich had a manifest sympathy for Paul Feyerabend and his ‘anything goes’. Once he recommended I read Feyerabend’s *Against method*; the title of the German version was actually *Gegen Methodenzwang*, somewhat better reflecting the author’s intention. I was allowed to borrow his personal copy from him, I spent a sleepless night with the book and on the next day (still with red eyes and a bad headache) I gave it back to Dietrich, stating that I was finished with the book—and with the author as well. Dietrich only raised his eyebrows: “Hmmm—so?” (Only much later I came back to Feyerabend’s writings and could appreciate his rhetorics a little bit better.)

Anyway—those discussions with Dietrich made me aware of the importance of conceptual problems in doing science, and particularly in building-up a scientific discipline. Despite a latency of many years, some of those issues found a remote echo in my later writings on the rôle of theory in

physiology research (Wackermann, 2006). Retrospectively, I would say that those debates shaped my view of science more deeply and permanently than I would ever expect.

In early 1993 my time in Zurich was over, a bunch of papers published, a few others in production, results of what I believed would be just an interesting intermezzo on my professional path. I moved back to Prague and in the following years was mostly occupied by commercial activities. However, Dietrich’s and my ways crossed time and again; we met at the EEG mapping meetings at various locations, Giessen, Warsaw, and Zurich again. When Dietrich attended an IPEG meeting in Prague, 1995, we used that opportunity to continue our discussions at a cup of coffee. These re-established contacts created a base for more co-operative work—although I was still bound to my Prague business and could do research only in spare hours—with Dietrich and colleagues from Switzerland, Hungary, and Japan. In Summer 1997 Dietrich told me he had found funding to employ me in Zurich again; really great news, as at that time I wished to leave my business and to return back to research. However, the way was not free immediately: I still had to wait for a work-permit for Switzerland. It was during this waiting time, in early 1998, that a new, totally unexpected possibility arose, namely, to build-up a psychophysiology laboratory at the Institute for Frontier Areas of Psychology in Freiburg, Germany.

This is not the place to tell the story of a difficult decision between Zurich and Freiburg; I will not enumerate all the factors involved; it may suffice to say that I finally decided for Freiburg. Importantly, Dietrich’s active mediation played an important rôle in that story; once again, he was there to induce another change in my life. Surely

it wouldn't make any sense to speculate whether Freiburg was the 'right' decision or not. I don't believe that there are right or wrong decisions; there are only decisions made or not made. The question 'what if?' is a foolish question, whether applied to one's individual life or to historical epochs and whole nations or cultures. The fact was that I was now located in Freiburg, not far from Zurich, and we were looking forward to a collaboration between our labs and workgroups, as good and productive as we had earlier under more difficult conditions.

Indeed, there was a lot of enthusiasm in the beginning; Dietrich was frequently visiting my lab in Freiburg and actively interested in the progress of building works, purchase of equipment, etc. And yet, the only co-operative work based on data acquired in our laboratory in Freiburg was a study on EEG correlates of sleep onset and ganzfeld-induced states (Wackermann, Pütz, Büchi, Strauch, & Lehmann, 2002). There were remarkable signs of research interests diverging between co-authors, already in the early phases of the study; then in the following years our research foci dissociated further. While I was increasingly attracted by problems of visual perception, time perception and measures of subjective time, I had nothing or only little to contribute to research on Dietrich's favourite topics, such as states of consciousness (hypnosis, meditation) and schizophrenia. The latest papers where we met as co-authors were on bi-stable perception (Müller et al., 2005) and schizophrenia (Lehmann et al., 2005), both date back to 2005. At least in the latter paper we came back to a topic treated in our early work (Wackermann, Lehmann, Michel, & Strik, 1993), namely, analysis of transition probabilities between microstates.

And, sadly, Dietrich's health was a limiting factor, too. As a result, our contacts loosened considerably. The last time Dietrich visited me in Freiburg was, I believe, May 2008, on the opportunity of a modest festivity we arranged to celebrate the ten-years anniversary of our department in Freiburg. This was also the year of profound changes; my department had to move, and subsequently we abandoned active work in electrophysiology. The chapter written for the collective work *Electrical Neuroimaging* (Wackermann & Allefeld, 2009), had to be my last contribution to the field.

Our connections with Dietrich were thus loosened, but not interrupted, and continued until the recent years. Because of his fragile health Dietrich avoided traveling, so the only opportunity to meet were my brief visits to Zurich; less frequent than in earlier years, but we could enjoy our conversations even more. During the long years of our acquaintance we both became aware of each other's sensitive points and learned how to pass by them smoothly. We were still discussing our research, now without going into non-essential details and without opening controversial issues; and we still liked commenting on the theatrical show of academic life, without taking those things (too) personally. — But there was more. In our late discussions we returned to the topics we were occupied with twenty years ago: the concept of functional microstates, the relations between microstates and higher-order (macro)states, the fundamental problems of microstates identification. For a short while we were even pondering possibilities of working together again on those recurrent issues of shared interest; but soon it turned out that this would not materialize. It was time to accept it and be ready to say good-bye.

Almost twenty-five years passed: a quarter of century, a significant period not only in one's

life, but also on the historical time-scale. Many things changed: the academic scene, the manner how science was and is being done, all in change: trends and fashions, great expectations, big words. In our late talks with Dietrich we commented on some of these phenomena, while leaving other phenomena better without comment. There was no doubt that the transformation would be irreversible. Times when one's individual urge to know and understand was the major motive for doing research, when one could find (at least relative) freedom and self-determination in science: those times are now over. Science of these days is more like industry—organized, normalized, standardized—rather than the pursuit of knowledge as we wished to have it some decades ago. What made Dietrich's person so fascinating was his preserving the values of the classic model of science—the unity of life-in-science and life-for-science, as I named it in the beginning of this paper. More could be said on these issues, but that would be a matter for another essay. May all that has been said above stand as my testimony of Dietrich Lehmann, as I knew him: great scientist and true friend.

I wish to thank Wolfgang Skrandies for his kind invitation to contribute to this special issue, and Robert Bishop for reading the manuscript and correcting the English.

References

- Başar, E., & Schürmann, M. (1997). Functional correlates of alphas. Panel discussion of the conference 'Alpha Processes in the Brain'. *International Journal of Psychophysiology*, 26(1–3), 455–474.
- Lehmann, D., Faber, P., Galderisi, S., Herrmann, W., Kinoshita, T., Koukkou, M., ... Koenig, T. (2005). EEG microstate duration and syntax in acute, medication-naïve, first-episode schizophrenia: a multi-center study. *Psychiatry Research*, 138(2), 141–156. doi: 10.1016/j.psychresns.2004.05.007
- Müller, T., Koenig, T., Wackermann, J., Kalus, P., Fallgatter, A., Strik, W., & Lehmann, D. (2005). Subsecond changes of global brain state in illusory multistable motion perception. *Journal of Neural Transmission*, 112(4), 565–576. doi: 10.1007/s00702-004-0194-z
- Wackermann, J. (2006). Rationality, universality, and individuality in a functional conception of theory. *International Journal of Psychophysiology*, 62(3), 411–426. doi: 10.1016/j.ijpsycho.2006.01.009
- Wackermann, J., & Allefeld, C. (2009). State space representation and global descriptors of brain electrical activity. In C. M. Michel, T. Koenig, D. Brandeis, L. R. R. Gianotti, & J. Wackermann (Eds.), *Electrical neuroimaging* (pp. 191–214). Cambridge University Press.
- Wackermann, J., Lehmann, D., Michel, C. M., & Strik, W. K. (1993). Adaptive segmentation of spontaneous EEG map series into spatially defined microstates. *International Journal of Psychophysiology*, 14(3), 269–283.
- Wackermann, J., Pütz, P., Büchi, S., Strauch, I., & Lehmann, D. (2002). Brain electrical activity and subjective experience during altered states of consciousness: ganzfeld and hypnagogic states. *International Journal of Psychophysiology*, 46(2), 123–146.

Dietrich Lehmann – Doctor honoris causa of the Friedrich Schiller University Jena

HERBERT WITTE

Institute of Medical Statistics, Computer Sciences and Documentation
Jena University Hospital, Friedrich Schiller University Jena, Germany

Abstract

In 1996 the Friedrich Schiller University (FSU) Jena awarded Prof. Dr. Dietrich Lehmann (1929–2014) an honorary doctorate for his pioneering and outstanding research results in neuroscience and his strong commitment to the development of neuroscience at FSU. D. Lehmann was an active supporter of neuroscientific research at the Institute of Pathological Physiology (Prof. Dr. Dr. Ulrich Zwiener 1942–2004) from 1986, with a focus on the advancement of the “Jena Mapping System”. He is known and greatly appreciated for his continual help and protection of researchers working under Communist regimes during this time period. After the fall of the Berlin Wall in 1989 he extended his activities as a member and spokesperson for the scientific advisory Board of the FSU’s priority research area “Clinically oriented Neuroscience”. In this position he helped to establish the Jena Biomagnetic Center. Dietrich Lehmann was always a welcome invited speaker at the International Hans Berger Congresses which took place in Jena. The Jena neuroscience community is deeply grateful to him for his consistent selfless and deeply personal support.

Introduction: Neuroscience at the University of Jena (Friedrich Schiller University)

The University of Jena was founded as an academic school in 1548 and raised to the status of a university in 1558. In the years between 1785–1803 (considered the “Golden Age” of Jena), a number of well-known German philosophers taught at the university, e.g. J. G. Fichte, F. W. J. Schelling, and G. F. W. Hegel. At the same time Friedrich Schiller was a professor of history and wrote some of his major literary and philosophical works here. As the minister of culture and higher education, Johann Wolfgang von Goethe was responsible for the de-

velopment of the University of Jena during this time. The early Romantics (Novalis, the brothers Schlegel, and W. Tieck) took advantage of Jena’s intellectually stimulating atmosphere. At the turn of the 19th century and on into the 20th century, Jena became a center of modern sciences, technology and industry through the leadership of Carl Zeiss, Ernst Abbe, and Otto Schott (N.N., 2010). The development of clinical neuroscience began during this time. In 1882 Otto Binswanger was appointed Professor of Psychiatry and Director of the mental asylum in Jena, a position he would hold for 37 years. His textbook “Epilepsy” (1899) became a standard text. He attracted distinguished coworkers,

such as Theodor Ziehen (1862–1950), Oskar Vogt (1870–1959), Korbinian Brodmann (1868–1918), and Hans Berger (1873–1941) (Hoff, 2002). Hans Berger not only discovered human electroencephalography, he was also introduced its clinical application. The utilization of equipment which was ahead of its time, the precise and self-critical clinical and experimental investigations, the inclusion of new methods of analysis, and his consistent engagement in interdisciplinary cooperation formed the basis for his successful work. In 1934 the University of Jena was renamed Friedrich Schiller University (FSU). After the Second World War the FSU underwent significant reconstruction and was quickly reopened and due to its excellent natural science research and the cooperation with the Zeiss Company the FSU was one of the universities in East Germany with worldwide reputation (N.N., 2010). Neuroscientific research was performed at the Physiological Institute and at the Clinic for Neurology as well as at the Clinic of Psychiatry. Although the field of neuroscience was actually at this time not at the forefront of innovative research, this situation was set to change after the appointment of Ulrich Zwiener as Professor of Pathological Physiology and as Director of the Institute of Pathological Physiology in 1979. On the basis of his studies on electrical brain activity using the EEG and other electrophysiological signals his intention was to establish a strong and internationally recognized neuroscientific research group. Projects on neonatal brain development using experimental and clinical EEG data were initiated. In 1986 he worked together with Dietrich Lehmann at the University of Zurich. Lehmann's results from EEG analysis, his findings on reference-free measures of brain field map strength (global field power), map landscape dissimilarity, and the segmenta-

tion of the brain field map series into temporal, functional microstates using numerical map landscape assessments were intellectually impressive for all institute members. During this phase I (H.W.) was a research assistant at the institute and responsible for the development of hardware-based as well as software-based analysis methods. U. Zwiener asked me whether a development of a mapping device including innovative analysis methods would be possible. This fitted in very well with my aims as I had just finished my habilitation thesis and was seeking new scientific challenges. After a reflection period of one day I gave him a very guarded and cautious answer: "We should try it". This short discussion provided the impetus for the "Jena EEG Mapping Project", the project to which Dietrich Lehmann dedicated himself so personally and wholeheartedly.

Dietrich Lehmann and the "Jena EEG Mapping Project" (1986–1989)

By this time the economic environment in the former GDR had deteriorated rapidly, i.e. public funding for research projects was very limited. Universities suffered from under-investment in modern research and computer technology; for example only 8-channel EEG devices were available and we worked with a PDP-8 (Digital Equipment Cooperation – DEC) compatible minicomputer which was produced by the Zeiss Company. Computer technology including memory and graphics capability was hopelessly obsolete, i.e. computing power was slow and graphic resolution inferior. In comparison from the early 1980s microcomputers (personal computers) were widespread and state-of-the-art in the West. East Germany was completely isolated from the development and availability of functional brain imaging techniques such as functional MRI and PET.

Despite these severe technological limitations, in addition to a depressed economy and the negative effects of totalitarian political structures (limited career opportunities for political opponents, travel and publication restrictions, minimal opportunities for international cooperation etc.) the project was initiated in September 1986. We connected two 8-channel EEG devices and by means of a self-made AD-converter, digitized 16-channel EEG data were available. Our equipment and setup at this time is depicted in Figure 1.

The computer for the data acquisition was made available by a group of mathematicians (Gert Griesbach, 1947–2001) which developed a software system for machine diagnostics. This analysis software system was called “ATISA” (Adaptive Time Series Analysis), where the type of algorithms were almost identical with those which we had used in the team of U. Zwiener, e.g. digital filtering, FFT-based spectrum, coherence and cepstrum analysis. G. Griesbach’s adaptive approaches were based on the theory of stochastic approximation which we later used for adaptive filters, thresholds and ARMA (autoregressive moving average) models (e.g. Schack, Bareshova, Griesbach, & Witte, 1995). Necessary artefact rejection and spike detection methods were already developed in my team (e.g. (Witte, Glaser, & Rother, 1987)) because we aimed at the development of intelligent (adaptive, model-based) detection and analysis algorithms (e.g. (Witte, Zwiener, Griesbach, Michels, & Hoyer, 1988)). A common goal was developed to link the methodological research activities of both groups into a cooperative project. The concept of an application of their methods to brain signals prompted enthusiastic motivation for the members of the Griesbach group. The project created a spirit of activity which radiated outwards and inspired

other research groups at FSU, e.g. physicists who developed a quantum interference device (SQUID) to record cardiomagnetic fields, and engineers who developed new automation and instrumentation. In less than half a year the project swiftly broadened its impact and became an official core university project. During this consolidation period both groups implemented a first version of a mapping system; for the graphical representation of the maps a television set was used (Figure 2A). A prototype of our mapping system was presented at the International Pathophysiology Congress which took place in September 1987 in Jena. Dietrich Lehmann was one of the invited speakers. This was our very first meeting and we immediately found common ground. When discussing our future concepts, he was very interested in our intention to utilize particular time-variant methods as basis algorithms for EEG mapping. We maintained frequent contact and he sent us multichannel EEG data (benchmark data for alpha EEG) in order to test our methodological approaches as well as providing electronic memory chips to increase the RAM (random access memory) size of our prototype system. His visit one year later allowed him to check our methodological advances. We were deeply grateful and stimulated by this visit as no one on the development team was allowed to travel to the West. In 1988/89 the “Jena EEG Mapping System” was composed of a fast acquisition and analysis computer and a modern personal computer for data storage, graphical representation, statistics etc. The analysis computer was equipped with a digital signal processor (DSP) board for a fast carrying out of the fast Fourier transform (FFT). This system is shown in Figure 2B. We used the FFT for the implementation of the time-variant analysis methods in the frequency domain,



Figure 1: EEG laboratory of the Institute of Pathological Physiology Jena (1987) with the Faraday cage, two coupled 8-channel EEG devices for 16-channel recordings and the computer for data digitalization (left).

e.g. the Hilbert and the Gabor transform. The Hilbert transform was implemented to compute time-variant (instantaneous) power and frequency map sequences.

It should be noted that different configurations of analysis and mapping systems have been manufactured as a limited series since 1988 and these systems have been used for technical analyses and EEG mapping. The core of the development team included more than 10 research assistants for advancement, optimization and programming of methods. In addition application teams for EEG, EP and EMG (electromyography) mapping as well

as for technical diagnosis existed. The software solutions were commercially distributed as PC software packages ("WATISA" – Adaptive Time Series Analysis for Windows™). Dietrich Lehmann aided us in locating helpful contacts in the "international market" and provided us insight into the important scientific developments within the EEG mapping community. It may be described that in this way he acted as an "antennae to the west" for us. During the International Workshop "Mathematical Modelling and Functional Imaging" which took place on 5th–7th November 1989 near Jena he was invited to participate in the contract nego-

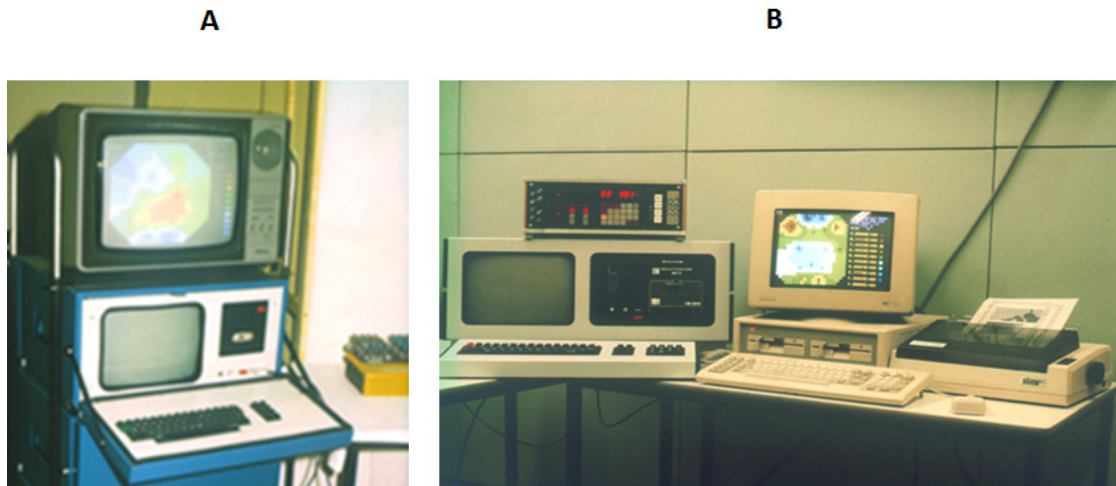


Figure 2: (A) Prototype of the “Jena EEG Mapping System” exhibited at the International Pathophysiology Congress held in Jena, September 1987. (B) Advanced Mapping System in 1988/89 composed of an acquisition-control (left) and an analysis (right) computer.

tiations with the NORAXON company (Finland). This company was strongly interested in a commercialization of our software system for surface EMG mapping (called “MyoMap”). The workshop (Figure 3) and the negotiations were successful and D. Lehmann traveled back to Zurich one day before the fall of the Berlin Wall. Germany, Europe and the world have changed in the intervening years.

Dietrich Lehmann’s impact on the development of the neurosciences at FSU since 1990

Due to changes in the political environment a free flow of people, information and ideas was now possible. Two weeks after the opening of the borders the EMG mapping system (NORAXON OY) was presented at the MEDICA 1989 fair in Duesseldorf. In 1990 Dietrich Lehmann invited me for a research visit in Zurich. He was interested in the mapping of the instantaneous power and fre-

quency of EEG signals which I had implemented on the basis of the Hilbert transform (Witte et al., 1990) which led to two cooperative publications (1992 and 1996 (Witte, Lehmann, Capaul, & Rother, 1992; Hoffmann, Skrandies, Lehmann, Witte, & Strobel, 1996)). In Figure 4 an instantaneous frequency map sequence of a checker board reversal VEP (Witte et al., 1992) is shown which was computed during this stay.

During this research visit I made the acquaintance of Christoph Michel and Daniel Brandeis who worked at that time in the Lehmann group. Shortly afterwards I met Wolfgang Skrandies who developed, together with D. Lehmann, many innovative analysis approaches. We utilized these methods for our own research and further benefited from the advancements performed by these excellent researchers. In 1990 an extensive renewal and modernization of FSU Jena began. While remaining true to its humanist tradition yet with a critical overview of the past, FSU resolved to achieve its special potential for the



Figure 3: Dietrich Lehmann^① during his key-note lecture “EEG-EP-mapping analysis by space-oriented segmentation” at the International Workshop “Mathematical Modelling and Functional Imaging” (Rudolstadt, November 1989). ^② Ulrich Zwiener, ^③ Herbert Witte.

future while keeping up its high academic standards in a unified Germany and Europe. Ulrich Zwiener initiated the establishment of the priority research area “Clinically oriented Neuroscience” in 1990. The development of the new research structures was supported by the Federal Ministry for Education, Science, Research and Technology (BMBF(T)) by a special funding program for the new federal states (NBL 1 - 3). This was one of five (later four) priority research areas of the medical faculty which also encompassed projects from other faculties of the FSU. Zwiener asked Dietrich Lehmann to serve as a member of the Scientific Advisory Board for this cluster funding (Center for Clinical Research (VKF) since 1995) and his answer was positive. Later he served as a

spokesperson of the Board. During this time he contributed substantially to the scientific orientation and goals of neuroscientific research in Jena. He performed these activities until 1997 and we interacted frequently because I was the scientific coordinator for the neuroscience cluster between 1993 and 1998. Dietrich Lehmann’s main scientific work was based on EEG and EEG analysis and he was not convinced of any existing hypotheses concerning the considerable superiority of the MEG over the EEG. Nevertheless, he strongly supported the intention of U. Zwiener to establish a biomagnetic center in Jena and he played a major role in the development of this project. The 2 x 31 channel Philips biomagnetometer was fully operational in 1994 (see Figure 5).

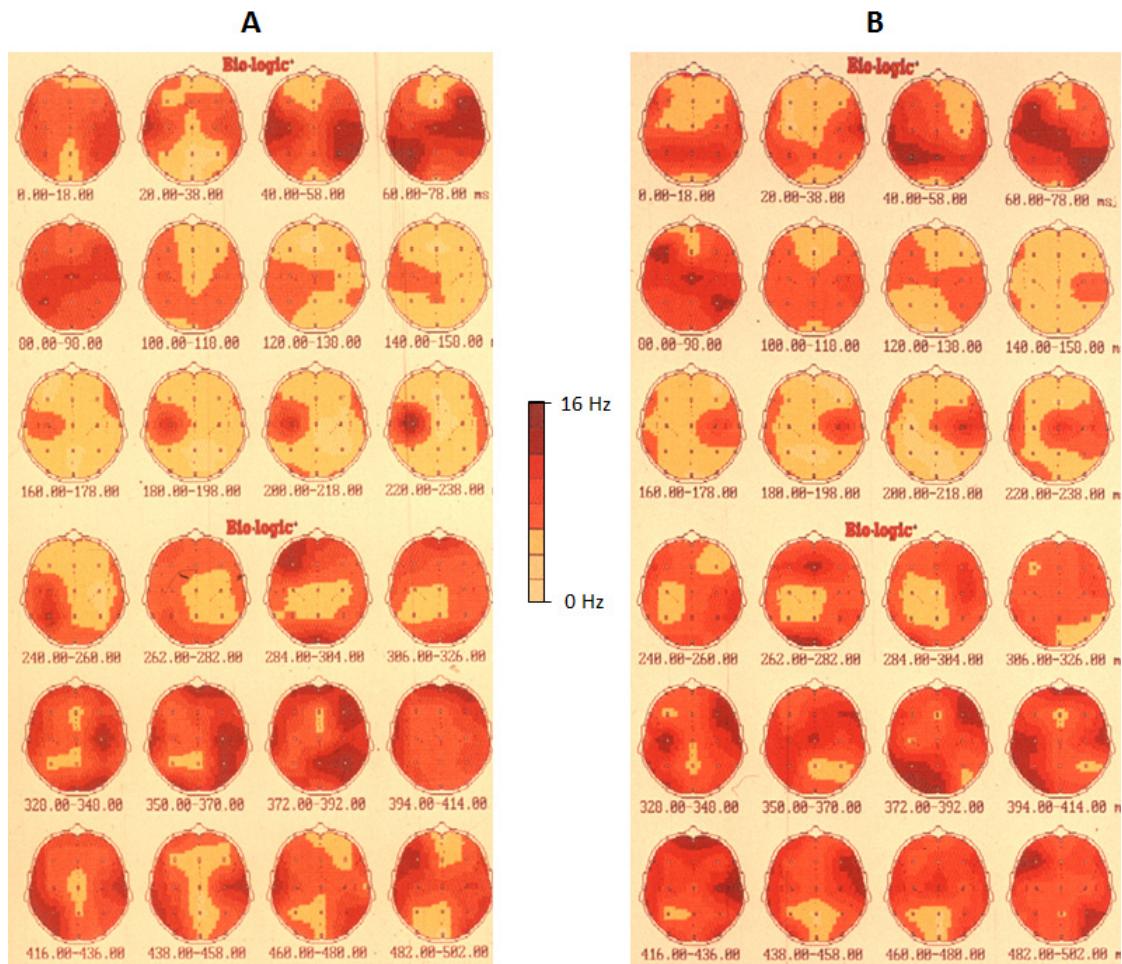


Figure 4: Map sequences (0–500 ms, grand mean results, group of 21 volunteers) of the instantaneous frequency of checker board reversal VEP (A – left hemiretinal stimulation, B – right hemiretinal stimulation). Each map represents the mean value of the given time epoch. All maps for both stimulations show mirrored structures.

The Biomagnetic Center Jena (BCJ) is currently equipped with three different systems: 306-channel Neuromag Vectorview whole-head MEG system 16-channel MicroSQUID system 195-channel AtB Argos 200 magnetocardiography system.

The establishment of the BCJ and the realization of other ambitious projects would not have been possible without his excellent assistance. There-

fore it was only logical for the neuroscience community at the FSU to apply for an appropriate distinction. In 1996, Dietrich Lehmann was awarded with an honorary doctorate from FSU for his exceptional contributions to neuroscience research and for his continual selfless and deeply personal support for the establishment of innovative neuroscience research at FSU (see Figure 6).



Figure 5: (A) First building in which the Biomagnetic Center Jena was housed. (B) 2 x 31 Philips biomagnetometer.

Dietrich Lehmann and the International Hans Berger Congresses (1991–1999)

Dietrich Lehmann was impressed by the scientific work and work style of Hans Berger. Lehmann's "microstates – atoms of thought" theory refers to Berger's vision to describe brain mechanisms of the human mind. D. Lehmann summarized these connections in a review article as follows (Lehmann, 1997): "Hans Berger started his work on the mechanisms of the human mind with EEG wave analysis, examining single time series. 70 years later, multichannel brain field recordings and data-driven analysis of the space-time data matrices has led to the description of putative building blocks of mentation, i.e. epochs of quasi-stable field configurations with durations in the sub-second range (called microstates), that are identified as steps or modes of conscious thoughts. The mirroring of the microstates structure in brain space and time might be what consciousness is made of." These connections to the

ideas of Berger formed the basis for his emotional attachment to Jena. Therefore, he supported the International Hans Berger Congresses as a member of the Scientific Congress Committee (1991, 1993, 1996, 1999) and as a highly welcomed key note speaker (see Figure 7). The congress series began in 1991 and only four Berger Congresses have taken place. Due to Berger's possible involvement in the fascist euthanasia program the congress series was not continued. Up to now, the allegations that have been raised against Berger have not been clarified.

A personal obituary

In the following years we met each other at other congresses and workshops and I personally met him for the last time in 2009 in Zurich on the occasion of his 80th birthday. The different facets of connections between Dietrich Lehmann and Jena which are described above reflect only the "official" side of the relationship between us. For me and my family Dietrich was a fatherly friend.



Während eines akademischen Aktes der Universität nahm gestern der international bekannte Züricher Neurophysiologe Prof. Dr. Dietrich Lehmann (Mitte) die Ehrenpromotion der Medizinischen Fakultät entgegen. Die Ehrung nahmen Rektor Prof. Dr. Georg Machnik (l.) und Dekan Prof. Dr. Eberhard Straube vor. (Foto: OTZ/Rybka)

Universität würdigt den Förderer der Jenaer Neurowissenschaften

Ehrenpromotion für den Züricher Professor Dr. Dietrich Lehmann

Jena (OTZ/L. Th.). Während eines akademischen Festaktes gestern in der Aula der Friedrich-Schiller-Universität verliehen Rektor Prof. Dr. Georg Machnik und der Dekan der Medizinischen Fakultät, Prof. Dr. Eberhard Straube, die Ehrendoktorwürde an den Züricher Mediziner Prof. Dr. Dietrich Lehmann.

Damit ehrt die Jenaer Universität den derzeit angesehensten Wissenschaftler auf dem Gebiet der Elektroenzephalographie (EEG), würdigte Prof. Dr. Herbert Witte den Schweizer Wissenschaftler in seiner Laudatio. Der Professor für Neurophysiologie an der Universität Zürich sei derzeit einer der produktivsten Hirnforscher, der schon frühzeitig mit verschiedenen Verfahren der elektrophysiologischen Registrierung von Hirnprozessen hervortrat, sagte Prof. Witte und verwies auf die

über 200 Artikel in den renommiertesten Zeitschriften dieses Fachgebietes und auf mehr als 400 wissenschaftliche Publikationen aus der Feder von Prof. Lehmann. Ohne Zweifel könne der Gelehrte zu den wesentlichen Wegbereitern moderner Verfahren der Analyse kognitiver Prozesse des menschlichen Gehirns gerechnet werden.

Den wohl wichtigsten Beitrag leistete Prof. Lehmann auf methodischem Gebiet. Dort erregte er internationales Aufsehen insbesondere mit Mappingverfahren und sogenannten Quellenanalysen, die heute auf dem Gebiet der kognitiven Neurowissenschaften nicht mehr wegzudenken sind.

Den Antrag zur Ehrenpromotion hatte die Jenaer Medizinische Fakultät zudem gestellt, um die langjährige Unterstützung des Wissenschaftlers zu würdigen, die er der Jenaer

Universität beim Aufbau der Neurowissenschaften zuteil werden ließ. Schon vor zehn Jahren - zu DDR-Zeiten - kam es zu persönlichen Kontakten zwischen dem Wissenschaftler und den Jenaer Medizinern, sagte Prof. Witte, „zu einer Zeit, als die Jenaer nicht nach Zürich reisen durften“. Seinerzeit stellte Prof. Lehmann der Medizinischen Fakultät die Ergebnisse seiner Untersuchungen zur Verfügung und ermöglichte zudem den Zugriff zu einem an der Universität Prag befindlichen EEG-Gerät, welches in Jena nicht zur Verfügung stand. Damals schon wurden die Voraussetzungen geschaffen für den Forschungsschwerpunkt „Klinisch-orientierte Neurowissenschaften“, der in den heutigen Verbund für „Klinische Forschung“ eingegangen ist und vom Bundesministerium gefördert wird.

Figure 6: Press release regarding the awarding of the Doctor honoris causa degree to Dietrich Lehmann (in the middle). The Dr. h. c.-certificate was given by the former Rector of the FSU (Prof. G. Machnik, left) and the former Dean of the Medical Faculty (Prof. E. Straube, right).



Figure 7: Dietrich Lehmann during the opening ceremony of the 3rd International Hans Berger Congress in 1996 (auditorium of the FSU).

I had the privilege of knowing him for more than 25 years. He was an excellent and internationally recognized scientist, a fine colleague and faithful friend, and I am sure that he will be greatly missed by all who knew him.

References

- Hoff, P. (2002). Otto Binswanger. *American Journal of Psychiatry*, 159, 358.
- Hoffmann, K., Skrandies, W., Lehmann, D., Witte, H., & Strobel, J. (1996). Instantaneous frequency maps, dipole models and potential distributions of pattern reversal-evoked potential fields for correct recognition of stimulated hemiretinae. *Evoked Potentials-Electroencephalography and Clinical Neurophysiology*, 100(6), 569–578.
- Lehmann, D. (1997). From EEG Waves to Brain Maps and to Microstates of Conscious Mentation. In H. Witte, U. Zwiener, B. Schack, & A. Doering (Eds.), *Quantitative and Topological EEG and MEG Analysis* (pp. 139–149). Jena, Erlangen: Druckhaus Mayer Verlag GMBH.
- N.N. (2010). Studying in Jena. *Advertisement brochure of the FSU*.
- Schack, B., Bareschova, E., Grieszbach, G., & Witte, H. (1995). Methods of dynamic spectral-analysis by self-exciting autoregressive moving average models and their application to analyzing biosignals. *Medical & Biological Engineering & Computing*, 33(3), 492–498.
- Witte, H., Glaser, S., & Rother, M. (1987). New spectral detection and elimination test algorithms of ECG and EOG artifacts in neonatal EEG recordings. *Medical & Biological Engineering & Computing*, 25(2), 127–130.
- Witte, H., Lehmann, D., Capaul, M., & Rother, M. (1992). Application of instantaneous frequency maps for quantification of visual evoked potentials. *Automedica*, 14, 133–143.
- Witte, H., Stallknecht, K., Ansorg, J., Grieszbach, G., Petranek, S., & Rother, M. (1990). Using discrete hilbert transform to realize a general methodical basis for dynamic EEG mapping. A methodical investigation. *Automedica*, 13, 1–13.
- Witte, H., Zwiener, U., Grieszbach, G., Michels, W., & Hoyer, D. (1988). Power Spectral Mapping (PSM) of neonatal EEG – Progress by using intelligent instrumentation. In J. Willems, J. Van Bemmelen, & J. Michel (Eds.), *Progress in computer-assisted function analysis* (pp. 351–356). North-Holland.

Dietrich Lehmann as a Neurophysiologist

WOLFGANG SKRANDIES

Institute of Physiology, Justus-Liebig University, 35392 Giessen, Germany

eMail: Wolfgang.Skrandies@physiologie.med.uni-giessen.de

In this brief contribution I will try to show Dietrich Lehmann's scientific work in a broader perspective. Of course, such an endeavor is heavily biased by personal experience and memories. In the scientific community Dietrich Lehmann is mainly known for his work on the development of multichannel EEG and ERP recordings and electrical brain mapping as well as for his keen interest in higher human brain function. This research mainly resulted in a substantial number of publications on the functional significance of the so-called microstates. His work encompasses many experimental studies and much insight into the "atoms of thought". I believe it is worth remembering that all of this work and these ideas are based on solid and basic neurophysiology as is evident from Dietrich Lehmann's first publications on cortical and subcortical functions in the cat brain (Creutzfeldt, Spehlmann, & Lehmann, 1961; Lehmann, Murata, & Koukkou, 1962) as well as on neurological patients described in his doctoral thesis (Lehmann, 1957). The foundation of this interest was probably established during the years spent with the eminent neurologist Richard Jung at the Department of Neurology in Freiburg.

My first encounter with Dietrich Lehmann was most memorable. On a cold and clear December afternoon in 1976 I had come to Zürich in order to discuss a potential doctoral fellowship with Dietrich Lehmann. After showing me the laboratory

there was only little "small talk" but very serious discussion of a wide range of scientific matters. Having just finished my thesis on the recording of single neurons and field potentials in the cat retina and cat brain (later published as Skrandies, Wässle, & Peichl, 1978) soon the question about the reference electrode came up (in retrospective this does not come as a surprise). Fortunately I could answer all concerns quite satisfactorily. In a lively atmosphere I learned that this question was important and central for the EEG world at that time, and I remember many discussions on this topic that continued for many years. It was meant to be a short visit only. However, when leaving I noticed that it was late at night and found my car covered with lots and lots of snow. Without noticing, much time had passed in an enjoyable atmosphere stirring many new ideas.

In 1977 the recording of EEG and evoked potentials was somehow adventurous since most of the equipment was very basic, and computer controlled experiments were widely unknown and only about to be developed. The laboratory was equipped with analogue hardware like Grass P511 amplifiers, a x/y plotter, a CAT (computer of averaging transients) and many, partly self-built electronic gadgets. For example, checkerboard reversal VEP stimuli could not simply be presented on a monitor but a slide of a checkerboard pattern had to be back-projected onto a translucent screen, and was inverted by a galvanometer-

mounted mirror, driven by a feedback-controlled amplifier. To understand the presentation mode of a simple visual stimulus entailed understanding of many technical details. This example also illustrates the importance of technical personnel like electronics engineers or a workshop able to build various devices in close cooperation with the researcher. Dietrich Lehmann's knowledge also covered such basic technical issues.

The center of the laboratory was a PDP-11/10 (later replaced by a PDP-11/34a) minicomputer which allowed – in combination with a specially built 48-channel amplifier and a 64-channel A/D converter system – multichannel EEG recordings. To my knowledge at that time such a multichannel recording system was unique throughout the world. The system worked highly reliably, although the computing power and memory of a minicomputer were less than what you find today in an ordinary cell phone. The laboratory was one large room where also sensory evoked potentials were recorded from neurological patients every day. For most patients and visitors the laboratory – full of electronic equipment and meters of seemingly cluttered BNC cables – was probably most intimidating.

Neurological cases were examined daily on a routine basis, and experiments on healthy volunteers were possible mainly late in the afternoon or in the early evening. There was much activity in the laboratory all day long. Dietrich Lehmann thought mainly about doing practical recordings and data analysis rather than just to sit at his desk. From early on I was told that “*interesting things do not happen in the library or in your study room but in the laboratory*”. If during a discussion a question arose it was quite normal not to further look for literature but to go to the laboratory and perform a little experiment. This turned out to

be most fruitful as it opened our eyes on how to judge some of the published data. Even today, in the century of impact factors and semi-automatic rapid publishing, it would be worthwhile and instructive to try to replicate some findings from the literature.

When the first reports appeared announcing that it might be possible to record not only EEG but also magnetic signals from the human brain (the MEG), we borrowed a single-channel SQUID system from a physicist of the Technical University (ETH). With Dietrich Lehmann's car, loaded with the system and several electronic devices, we set out to the Swiss Alps, and late at night in the lobby of a hotel remote from most sources of electric and magnetic artifacts we measured spontaneous MEG activity. As expected there was alpha activity that was blocked by opening the eyes. This was enough to convince us that MEG as a complementary signal allowed to measure similar neural processes as known from decades of EEG research.

It was a small research group with some outside funding and the continuous support of Günther Baumgartner, the head of Neurology. Coming from the “Jung-School” in Freiburg, in addition to his work in clinical neurology he was interested in many fields. This was reflected by various research groups established in the department where a range of topics like single unit recordings in the monkey visual cortex, analysis of the oculomotor system, and questions of higher brain function and neuropsychology were studied. At that time Zürich offered a lively atmosphere with local scientists interested in neuroscience (Konrad Akert, Max Anliker, Alexander Borbély, Michel Cuenod, Volker Henn, Günther Niemeyer, Mario Wiesendanger, Gazi Yasargil, just to name a few) as well as scientific guests from all over

the world. There were regular seminars on scientific topics that attracted not only local persons but also guests from far away (for example, Lothar Spillmann came regularly from Freiburg to attend such talks). This interdisciplinary climate ensured a very wide view of various aspects of neuroscience.

In Dietrich Lehmann's laboratory guests from many countries as well as doctoral students from medicine performed various neurophysiological studies. In the 1970s the routine recording of sensory evoked potentials was more of an art than of an everyday method. Visual evoked potentials had been shown to be of use for the diagnosis of multiple sclerosis only a few years before, and the first publications on the successful recording of human brainstem auditory evoked activity had just appeared. Dietrich Lehmann was sincerely interested in developing such methods for use in clinical neurology, and a summary of this clinical work was published a few years later (Lehmann, Gabathuler, Soukos, Skrandies, & Baumgartner, 1980; Lehmann & Soukos, 1982).

Dietrich Lehmann had been working on binocular interactions during his time in Pasadena, and it was most fortunate that Bela Julesz spent a few months in Zürich as a visiting professor. Being a guest of Günter Baumgartner, it was easy to approach Bela Julesz and convince him that the recording of brain activity elicited by the famous dynamic random dot stereograms would be most interesting. After solving many small and larger technical problems and recruiting a motivated medical student, we did multichannel recordings during 3D vision. In those days computers were slow and computing power was marginal, so special hardware brought by Bela Julesz was used in combination with a PDP-11/40 computer located in a different laboratory down the hall in order

to present stimuli (dynamic random dot patterns, online generated at 100 frames/s) while in the laboratory the PDP-11/10 was busy with sampling the multichannel EEG. This work finally resulted in the analysis of processes involved in the handling of binocular visual input by the human visual cortex (Lehmann, Skrandies, & Lindenmaier, 1978). A related evoked potential study on functional differences between the upper and lower retinal halves produced many scalp potential maps. At that time computer graphics was in its infancy, and potential maps were printed on seemingly endless computer paper by a LA36 teletype printer. This took hours and hours, and for a final figure of publishable quality, all of this had to be redrawn with a pen and India ink. Of course, it was quite different from rapidly clicking through a software menu but it resulted in interesting data and insights about human visual information processing (Lehmann & Skrandies, 1979). More or less simultaneously there was interest in language processing, and experimental work was performed by Warren Brown who examined 16 channel recordings of word-evoked brain activity (Brown, Lehmann, & Marsh, 1980).

In August 1978 Dietrich Lehmann was the co-organizer (with Enoch Callaway) of an international conference on averaged evoked potentials that was held at Konstanz with Rudolf Cohen as the local host. Here the *crème de la crème* of EEG and evoked potential research met in order to discuss the state of the art in human electrophysiology. In my memory these were four most inspiring days where nearly all influential experts from around the world had gathered. The contributions were compiled in a book that appeared one year later, and for many years these proceedings were considered a source book covering evoked potential research from very basic methodological

questions to its practical application in neurology and psychiatry (Lehmann & Callaway, 1979).

Good contacts to the Department of Neurosurgery allowed access to patients with intracranial electrodes. This finally resulted in a fairly large data set with both intracranial EEG and scalp-recorded signals where dipole modeling, scalp field distributions, and intracranial activity could be compared directly (Lehmann, Darcey, & Skrandies, 1982). Looking back at these times it is almost unbelievable that Dietrich Lehmann was simultaneously involved in projects on sleep EEG (Lehmann, Dumermuth, & Meier, 1979; Borbély, Baumann, Brandeis, Strauch, & Lehmann, 1981) and dreaming (Lehmann, Koukkou, & Andreae, 1979) as well as in research on other topics. All colleagues present in the laboratory were involved in various research fields at the same time, adding individual expertise. These projects were widely and intensely discussed, and there was no sharp border between different projects. As mentioned above, “small talk” was not encouraged, but any topic relating to “hard” data and data analysis could be reviewed anywhere: in the laboratory, in the cafeteria, in local restaurants or in the lobby of the *Grandhotel Dolder* and in the café of the *Hotel Baur au Lac* where we sometimes escaped in order to write abstracts for a conference or the draft of a paper by hand – resulting in a manuscript in its truest sense.

It was this honest and deep interest in scientific issues which established the atmosphere for fruitful discussions and new discoveries that laid the groundwork for the future methodological work on topographical EEG mapping, and the application of this methodology to questions of basic and higher human brain function. All of this has definitely influenced the thinking of many

guests, doctoral and post-doctoral students who had worked in the Zürich laboratory.

I hope this brief semi-historical account illustrates Dietrich Lehmann’s accomplishment in the field of neuroscience. It should be clear that this broad approach exceeds the rather narrow concept of topographic mapping that has meanwhile become a standard method in human neurophysiology. All who had the privilege to meet Dietrich Lehmann personally will probably agree that we have lost a fine and gentle person, and an eminent scientist and true researcher.

I wish to thank Robert Snipes and Ann Ebberson for proofreading this text.

References

- Borbély, A., Baumann, F., Brandeis, D., Strauch, I., & Lehmann, D. (1981). Sleep deprivation: Effect on sleep stages and EEG power density in man. *Electroenceph. Clin. Neurophysiol*, 51, 483–493.
- Brown, W., Lehmann, D., & Marsh, J. (1980). Linguistic meaning-related differences in evoked potential topography: English, Swiss-German and Imagined. *Brain and Language*, 11, 340–353.
- Creutzfeldt, O., Spehlmann, R., & Lehmann, D. (1961). Veränderung der Neuronaktivität des visuellen Cortex durch Reizung der substantia reticularis mesencephali. In R. Jung & H. Kornhuber (Eds.), *The Visual System: Neurophysiology and Psychophysics* (pp. 351–363). Berlin: Springer.
- Lehmann, D. (1957). Klinische Beiträge zur Möglichkeit der Differentialdiagnose zwischen Paralysis agitans und postencephalitischem Parkinsonismus. *Med. Dissertation, Universität Heidelberg*.

- Lehmann, D., & Callaway, E. (Eds.). (1979). *Human Evoked Potentials: Applications and Problems*. London: Plenum.
- Lehmann, D., Darcey, T. M., & Skrandies, W. (1982). Intracerebral and scalp fields evoked by hemiretinal checkerboard reversal, and modeling of their dipole generators. *Adv Neurol*, 32, 41-48.
- Lehmann, D., Dumermuth, G., & Meier, C. (1979). High interhemispheric EEG coherence during REM periods in allnight analysis of human EEG. *Sleep Res.*, 8, 28.
- Lehmann, D., Gabathuler, U., Soukos, I., Skrandies, W., & Baumgartner, G. (1980). Nutzen evozierter EEG-Potentiale für die MS-Frühdagnostik: visuelle versus akustische und sensorische Reizung. In H. Reiser & G. Schnaberth (Eds.), *Fortschritte der technischen Medizin in der neurologischen Diagnostik* (pp. 225–228). Wien: Neurol. Univ. Klinik / Siemens.
- Lehmann, D., Koukkou, M., & Andreae, A. (1979). Daydreaming mentation and EEG patterns. *Sleep Res.*, 8, 154.
- Lehmann, D., Murata, K., & Koukkou, M. (1962). Simultane Periodik der Neuronaktivität in verschiedenen Cortexfeldern der Katze. *Naturwissenschaften*, 49, 611–612.
- Lehmann, D., & Skrandies, W. (1979). Multichannel evoked potential fields show different properties of human upper and lower hemiretinal systems. *Exp. Brain Res.*, 35, 151–159.
- Lehmann, D., Skrandies, W., & Lindenmaier, C. (1978). Sustained cortical potentials evoked in humans by binocularly correlated, uncorrelated and disparate dynamic random-dot stimuli. *Neuroscience Letters*, 10, 129–134.
- Lehmann, D., & Soukos, I. (1982). Visuell evozierte Potentiale und Hirnstamm-Klick-Potentiale in der Frühdagnostik der multiplen Sklerose: Statistik. *Nervenarzt*, 53, 327–333.
- Skrandies, W., Wässle, H., & Peichl, L. (1978). Are field potentials an appropriate method for demonstrating connections in the brain? *Experimental Neurology*, 60, 509–521.

EEG of two persons during their roles as spiritual trance healer and as client – a pilot study

P. L. FABER, P. MILZ, D. LEHMANN^(† 2014)

The KEY Institute for Brain-Mind Research, Department of Psychiatry, Psychotherapy and Psychosomatics
University Hospital for Psychiatry, CH-8032 Zürich, Switzerland

Abstract

Two experienced spiritual (trance) healers who occasionally treat each other were recorded simultaneously, each with 27 EEG channels. The participants alternated their roles as healer and client (8 runs of 15 min: each 4 times healer, 4 times client). FFT spectral analysis was done using average reference. Spectra were averaged across the 27 channels. Power was integrated for each of the eight frequency bands (delta through gamma). The eight simultaneous results of the healing runs (client vs healer condition) were statistically compared (frequency band-wise ANOVA). In their role as healer compared to their role as client, both participants showed less power in the function-inhibiting delta and function-facilitating beta-3 EEG frequency bands. In sum, this pilot study of spiritual (trance) healing found distinct EEG states (common to both participants) that combined EEG characteristics of functional inhibition and functional facilitation in healer and client which cannot be reduced to changes in drowsiness or alertness.

Preface

The following report is the result of one of the last projects Dietrich Lehmann worked on before he passed away on June 16th, 2014. He pushed this project forward despite our reservation towards it because he felt it was important in two ways: its topic and its methodology.

Dietrich has always been interested in topics deviating from the scientific mainstream. He was one of the first to study meditation (Hebert & Lehmann, 1977) and one of the first to study neurofeedback (Lehmann, Lang, & de Bruyne, 1976). Altered states of consciousness (Vaitl et al., 2013) were of particular interest to him and he did not restrict his inquisitive mind to meditation (Faber et al., 2014; Hebert & Lehmann, 1977; Lehmann, Faber, Achermann, et al., 2001; Lehmann et al.,

2012; Milz, Faber, Lehmann, Kochi, & Pascual-Marqui, 2014) or hypnosis (Cardeña et al., 2012; Isotani et al., 2001; Katayama et al., 2007; Lehmann, Faber, Isotani, & Wohlgemuth, 2001). In fact, under his supervision, we once collected EEG data from a medium channeling an entity that answered predefined questions. On another occasion, we received EEG data from a medium describing photos hidden in envelopes and unknown to him. Difficulties on the side of the participants to adhere to the strict research protocol in the first study and difficulties with the synchronization of the received EEG data with the voice recordings in the second study resulted in the discontinuation of these projects. They did not meet Dietrich's high scientific requirements.

However, Dietrich's interest in pursuing these fringe EEG studies did not lessen and he continued coming up with new ideas for such investigations. Even though these studies stirred our interest, Dietrich often met a certain reservation on our side since we were missing a clear hypothesis. He just blankly looked at us, saying: "Aren't you curious as to what happens in the brain when someone does something that is believed to be impossible?" Our hesitation as to possible conclusions of such experiments was always countered by his simple but strong desire to find out how things really are. He would prefer good data over a good theory any day! "Let's get the data and let's describe whatever we find; let others worry about theories!" Theories are like flies on dogs, he would say. "Let us look at the data as unbiased as we can."

The present report concerns one such exploratory study on the fringe of what is currently being investigated. Dietrich personally met with two trance healers, discussed their practice with them in detail, even had sessions with one of them and ensured their willingness to take part in an EEG study. This was in 2010. At the time Dietrich saw another reason for this project, one that he deemed at least equally important as its non-mainstream topic: its methodology, namely the simultaneous EEG recordings of healer and client. The methodology of simultaneous recording of two or more subjects is known as hyper-scanning (Montague et al., 2002). For years, Dietrich had been convinced that simultaneous EEG recordings would become the next big thing in the field. Indeed, meanwhile, several studies were published describing simultaneous EEG recordings on two or more participants (e.g. Astolfi et al., 2014; Dumas, 2011; Dumas, Nadel, Soussignan, Martinerie, & Garnero, 2010; Hachmeister, Finke,

& Ritter, 2014; Järvelä, Kivikangas, Kätsyri, & Ravaja, 2013; Konvalinka & Roepstorff, 2012; Sängler, Müller, & Lindenberger, 2012).

Our reservation analyzing this data was twofold. Firstly, one of the two participants was left- and the other right-handed and secondly, one participant was female and the other male. Considering the effects of these diverging participant characteristics on the EEG, a meaningful outcome of the study became rather doubtful to us. Dietrich was not very happy about these circumstances either but he relentlessly pushed us to analyze the recorded data and his incredible gift for finding patterns in any kind of data worked miracles again. Despite all the differences between the two participants, there were obvious state-dependent commonalities too and these commonalities are reported here.

We have been working intermittently on this report with Dietrich and shortly before he passed away, he handed us the latest draft of the manuscript and told us that he would have to leave it to us to publish these results. We finalized the manuscript by filling in a few small gaps but mostly left it as we had received it from Dietrich.

We are grateful to have had the opportunity to learn from Dietrich Lehmann for so many years. We stand in awe of his clarity of mind, we appreciate his wisdom that nothing is off topic, that everything can and should be studied with an open mind and we celebrate his consistent, meticulous and always insightful bottom-up data analysis approach. Through him, we learned how ethical, accountable, and strict research is to be done. And above all, we miss his kindness and great humor.

P. Faber, P. Milz

Introduction

Spiritual (trance) healing is becoming increasingly popular as a complementary and alternative medicine approach.

The present study examined in which way the EEG brain state of a person who performs spiritual (trance) healing as 'healer' differs from the EEG brain state of the same person when receiving spiritual (trance) healing as 'client'. We also examined whether the differences between the brain state as healer and client are similar in two different persons. We are not aware of papers that investigated these questions.

Studying these questions became possible because two experienced spiritual (trance) healers who also occasionally treated each other for minor health problems (headache, stomach irritation) volunteered to have their EEG recorded while they alternated their roles of healer and client.

The two healers that we studied told us that during healing they go into a trance-like state (Voggenhuber, 2009, p. 142) where they open themselves to the energy of the spiritual world that then flows through them and via their hand into the body of the client (Hodges & Scofield, 1995, p.3). They note that healing is effortless (Voggenhuber, 2009, p. 142), but requires the readiness and ability to open oneself to the energy flow. Subjectively, they feel that the trance is deeper when the treated disease is more serious – but they want no information from the client about the nature of the disease (Voggenhuber, 2009, p. 143).

We hypothesized that there are differences in the EEG power spectra between the roles as healers and as clients, and that these power spectra differences are similar in both participants.

Methods

Two experienced healers, Mr Pascal Voggenhuber ('PV', 30 y/o) and Ms Bahar Yilmaz ('BY', 26 y/o) volunteered for this study. The recordings were done on June 28, 2010.

From each of the two participants, scalp EEG data were recorded in 27 scalp EEG channels simultaneously and continually, using "Easy Cap" (Hersching-Breitbrunn, Germany) electrode caps and a 64-channel (M&I Ltd., Prague, Czech Republic) EEG system (bandpass 0.5-100 Hz, digitized at 250 samples/sec/channel). The scalp electrodes were at the following locations of the International 10-10 System (Nuwer et al., 1998): Fp1/2, Fpz, F3/4, Fz, F7/8, FC1/2, T7/8, C3/4, Cz, CP1/2, P7/8, P3/4, Pz, PO3/4, O1/2, Oz. In addition, eye movements were recorded with electrodes under the left eye and at the outer canthus of the right eye.

After electrode attachment, the participants were comfortably seated in the light- sound- and electrically shielded recording chamber with an intercom to the adjacent room with the experimenters. As healers, they lightly placed a hand just below the neck on the back of the client. Since PV is left-handed and BY right-handed, PV was seated to the right of BY so that changing seats was not necessary when the roles were changed between healer and client.

The recording protocol was as follows: At first, 4 minutes of no-task resting were recorded. Then, the two participants alternated their roles as spiritual (trance) healer and client in 8 healer-client recording runs of 15 minutes each: each participant acted 4 times as healer, and 4 times as client (Table 1). During these 8 runs, both participants had their eyes closed. Before and after each healer-client recording run, 2 minutes of EEG during no-task eyes-closed resting was recorded.

Table 1: The 8 recording runs where the roles of PV and BY alternated between healer and client.

Run #	PV	BY	minutes	
1	<i>Healer</i>	<i>Client</i>	15	
2	<i>Client</i>	<i>Healer</i>	15	
<i>Break</i>			5	
3	<i>Healer</i>	<i>Client</i>	15	
4	<i>Client</i>	<i>Healer</i>	15	
<i>Lunch break</i>			60	
5	<i>Client</i>	<i>Healer</i>	15	
6	<i>Healer</i>	<i>Client</i>	15	
<i>Break</i>			5	
7	<i>Client</i>	<i>Healer</i>	15	
8	<i>Healer</i>	<i>Client</i>	15	

Off-line, the 27-channel EEG data was artifacted first by linearly interpolating bad channels, then by correcting eye movement artifacts using the ocular ICA algorithm implemented in Brain Vision Analyzer 2.0 software (<http://www.brainproducts.com>) and finally by visually inspecting and manually marking remaining eye, muscle or movement artifacts. Only those simultaneous 2-second epochs of EEG that were free of artifacts in both recordings were exported for further analysis. After artifacting, there were on average 318 (SD=34.1) EEG epochs of 2-seconds available for analysis per healer/patient session.

FFT spectral analysis of the artifact-free 2-second-epochs was done after re-referencing the data to average reference for each participant. The power values of the spectra were averaged across the 27 channels. Power values were integrated for each of the statistically independent EEG frequency bands (Kubicki, Her-

rman, Fichte, & Freund, 1979; Niedermeyer & da Silva, 2005, p. 1234) of delta (1.5–6 Hz), theta (6.5–8 Hz), alpha-1 (8.5–10 Hz), alpha-2 (10.5–12 Hz), beta-1 (12.5–18 Hz), beta-2 (18.5–21 Hz), and beta-3 (21.5–30 Hz), and of an additional gamma band (35–44 Hz).

For each of the eight EEG frequency bands, a one-way ANOVA was computed with band power as dependent variable and the three independent variables: 'role' (healer vs. client), 'participant' (BY vs. PV) and 'run' (1 through 8). Results where the variable 'role' reached $p < 0.10$ are reported.

Results

The band-wise ANOVAs yielded differences between the participants' roles as healer or client in the delta and beta-3 EEG frequency bands.

In the delta band, the ANOVA yielded for role $F(1,6) = 53.84, p = 0.0003$ (partial $\eta^2 = 0.900$), for participant $F((1,6) = 19.28, p = 0.005$, and for run $F(7,6) = 11.84, p = 0.004$.

In the beta-3 band, the ANOVA yielded for role $F(1,6) = 5.10, p = 0.065$ (partial $\eta^2 = 0.459$), for participant: $F(1,6) = 97.83, p = 0.00006$, and for run: $F(7,6) = 3.56, p = 0.072$.

In both frequency bands, power was lower during the participants' role as healer than as client (illustrated in Figure 1). Also in both frequency bands, power was higher for PV than BY, and power increased from run 1 to 8.

Discussion

The results supported both hypotheses. The healer role compared to the client role was associated in both participants with lower power in the low frequency EEG delta band and in the fast frequency EEG beta-3 band. EEG oscillations

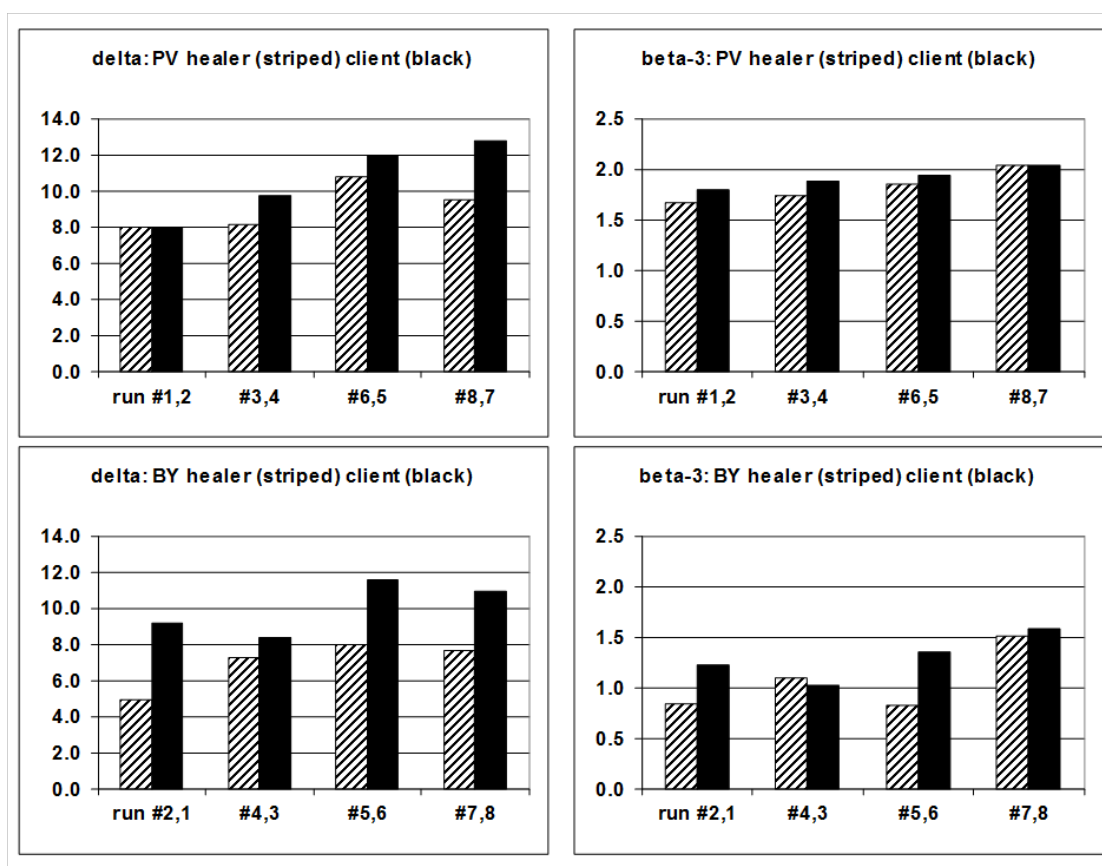


Figure 1: Mean power in the EEG delta and beta-3 frequency bands across all 27 recording channels during the two participants' (PV and BY) role as healer and as client; upper graph: PV, lower graph: BY.

from slow to fast frequencies in terms of information processing have the functional significance from inhibition to facilitation (Makeig & Jung, 1995; Niedermeyer & da Silva, 2005; O'Gorman et al., 2013). Thus, the present findings functionally contradict each other. The two observed differences also point in opposite directions on the EEG scale of vigilance where decrease in vigilance implies increase of slow frequency power while increase in vigilance implies increase of fast frequency power. Further, during sleep, power of the slow delta frequency is inversely related to power of the fast high-beta frequency (Dumermuth et al., 1983; Uchida, Maloney, & Feinberg, 1992).

These facts suggest that assuming a role as healer and client initiates vigilance-independent specific functional states.

Important questions need clarification: Are the changes in different healers and in different clients similar to those observed here? Are the EEG changes in the healer different when he/she has a different client? Likewise, are the changes in the client different when there is a different healer?

In sum, this pilot study of spiritual (trance) healing in two persons revealed distinct EEG states that combined EEG characteristics of functional inhibition and functional facilitation in healer and client that cannot be reduced to changes towards

drowsiness or alertness. It also showed that similar EEG differences between healer and client role occurred in two different persons.

References

- Astolfi, L., Toppi, J., Vogel, P., Mattia, D., Babiloni, F., Ciaramidaro, A., & Siniatchkin, M. (2014). Investigating the neural basis of co-operative joint action. An EEG hyperscanning study.. (Paper presented at the Engineering in Medicine and Biology Society (EMBC))
- Cardeña, E., Lehmann, D., Faber, P., Jönsson, P., Milz, P., Pascual-Marqui, R., & Kochi, K. (2012). EEG sLORETA functional imaging during hypnotic arm levitation and voluntary arm lifting. *International Journal of Clinical and Experimental Hypnosis*, 60(1), 31–53.
- Dumas, G. (2011). Towards a two-body neuroscience. *Communicative & integrative biology*(3), 349–352.
- Dumas, G., Nadel, J., Soussignan, R., Martinerie, J., & Garnero, L. (2010). Inter-brain synchronization during social interaction. *PloS one*, 5(8), e12166.
- Dumermuth, G., Lange, B., Lehmann, D., Meier, C., Dinkelmann, R., & Molinari, L. (1983). Spectral analysis of all-night sleep EEG in healthy adults. *European neurology*, 22(5)), 322–339.
- Faber, P., Lehmann, D., Gianotti, L., Milz, P., Pascual-Marqui, R., Held, M., & Kochi, K. (2014). Zazen meditation and no-task resting EEG compared with LORETA intracortical source localization. *Cognitive processing*, 1–10.
- Hachmeister, N., Finke, A., & Ritter, H. (2014). Does machine-mediated interaction induce inter-brain synchrony?—A hyperscanning study.. (Paper presented at the Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE)
- Hebert, R., & Lehmann, D. (1977). Theta bursts: an EEG pattern in normal subjects practising the transcendental meditation technique. *Electroencephalography and clinical neurophysiology*, 42(3), 397–405.
- Hodges, R., & Scofield, A. (1995). Is spiritual healing a valid and effective therapy? *Journal of the Royal Society of Medicine*, 88(4), 203–207.
- Isotani, T., Lehmann, D., Pascual-Marqui, R., Kochi, K., Wackermann, J., Saito, N., & Sasada, K. (2001). EEG source localization and global dimensional complexity in high-and low-hypnotizable subjects: A pilot study. *Neuropsychobiology*, 44(4), 192–198.
- Järvelä, S., Kivikangas, J., Kätsyri, J., & Ravaja, N. (2013). Physiological linkage of dyadic gaming experience. *Simulation & Gaming*.
- Katayama, H., Gianotti, L., Isotani, T., Faber, P., Sasada, K., Kinoshita, T., & Lehmann, D. (2007). Classes of multichannel EEG microstates in light and deep hypnotic conditions. *Brain topography*, 20(1), 7–14.
- Konvalinka, I., & Roepstorff, A. (2012). The two-brain approach: how can mutually interacting brains teach us something about social interaction? *Frontiers in human neuroscience*, 6.
- Kubicki, S., Herrmann, W., Fichte, K., & Freund, G. (1979). Reflections on the topics: EEG frequency bands and regulation of vigilance. *Pharmakopsychiatrie, Neuro-Psychopharmakologie*, 12(2), 237–245.
- Lehmann, D., Faber, P., Achermann, P., Jeanmonod, D., Gianotti, L., & Pizzagalli, D. (2001). Brain sources of EEG gamma fre-

- quency during volitionally meditation-induced, altered states of consciousness, and experience of the self. *Psychiatry Research: Neuroimaging*, 108(2), 111–121.
- Lehmann, D., Faber, P., Isotani, T., & Wohlge-muth, P. (2001). Source locations of EEG fre-quency bands during hypnotic arm levitation: A pilot study. *Contemporary Hypnosis*, 18(3), 120–127.
- Lehmann, D., Faber, P., Tei, S., Pascual-Marqui, R., Milz, P., & Kochi, K. (2012). Reduced func-tional connectivity between cortical sources in five meditation traditions detected with lagged coherence using EEG tomography. *Neuroim-age*, 60(2), 1574–1586.
- Lehmann, D., Lang, W., & de Bruyne, P. (1976). Kontrolliertes EEG-Alpha-Feedback-Training bei Gesunden und Kopfschmerzpa-tienten. *Archiv für Psychiatrie und Ner-venkrankheiten*, 221, 331–343.
- Makeig, S., & Jung, T.-P. (1995). Changes in alertness are a principal component of vari-ance in the EEG spectrum. *Neuroreport*, 7(1), 213–216.
- Milz, P., Faber, P., Lehmann, D., Kochi, K., & Pascual-Marqui, R. (2014). sLORETA intra-cortical lagged coherence during breath count-ing in meditation-naïve participants. *Frontiers in human neuroscience*, 8.
- Montague, P., Berns, G., Cohen, J., McClure, S., Pagnoni, G., Dhamala, M., & Apple, N. (2002). Hyperscanning: simultaneous fMRI during linked social interactions. *Neuroimage*. *Neuroimage*, 16(4), 1159–1164.
- Niedermeyer, E., & da Silva, F. (2005). *Elec-troencephalography: basic principles, clinical applications, and related field*. Lippincott Williams & Wilkins.
- Nuwer, M., Comi, G., Emerson, R., Fuglsang-Frederiksen, A., Guérit, J.-M., Hinrichs, H., ... Rappelsburger, P. (1998). IFCN stan-dards for digital recording of clinical EEG. *Elec-troencephalography and clinical neurophysiol-ogy*, 106(3), 259–261.
- O’Gorman, R., Poil, S.-S., Brandeis, D., Klaver, P., Bollmann, S., Ghisleni, C., ... Alsop, D. (2013). Coupling between resting cerebral per-fusion and EEG. *Brain topography*, 26(3), 442–457.
- Sänger, J., Müller, V., & Lindenberger, U. (2012). Intra- and interbrain synchronization and network properties when playing guitar in duets. *Frontiers in human neuroscience*, 6(312).
- Uchida, S., Maloney, T., & Feinberg, I. (1992). Beta (20–28 Hz) and delta (0.3–3 Hz) EEGs oscillate reciprocally across NREM and REM sleep. *Sleep*, 15(4), 352–358.
- Vaitl, D., Birbaumer, N., Gruzelier, J., Jamieson, G., Kotchoubey, B., Kübler, A., & Weiss, T. (2013). Psychobiology of altered states of con-sciousness. *Psychology of Consciousness: The-ory, Research, and Practice*, 1(0), 2–47.
- Voggenhuber, P. (2009). *Entdecke deinen Geist-führer: Wie uns Engel und geistige Wesen be-gleiten*. (Giger Verlag)

EEG manifested brain functional states with state-dependent information processing: a short review of the concept from the sixties to today

MARTHA KOUKKOU

The KEY Institute for Brain-Mind Research, Department of Psychiatry, Psychotherapy and Psychosomatics
University Hospital for Psychiatry Zürich, Switzerland

The initial research topic of Dietrich Lehmann and Martha Koukkou's work, which led to the formulation of the concept of EEG manifested brain functional states with state-dependent information processing was the use of the EEG to:

1. Investigate the EEG correlates of learning and memory during wakefulness and sleep (Koukkou & Lehmann, 1968; Lehmann & Koukkou, 1974) and
2. to search for relations between ongoing EEG activity and different spontaneous or elicited reports of the subjects' experiences (Koukkou, Dittrich, & Lehmann, 1975; Koukkou & Lehmann, 1976; Lehmann, Koukkou, & Andreae, 1981).

It was hypothesized: classes of spontaneous private events, and classes of ongoing spontaneous EEG activity, and their mutual correlations may be established.

In the article in the book edited by G. Pfurtscheller (Lehmann & Koukkou, 1980), we review briefly some of the studies we did, the experimental approaches were used and the sort of information it was obtained. It is concluded: "The experimental strategies used in these studies permit to describe,

in EEG terms, different short-lasting brain functional states which correlate with general types or strategies of spontaneous human mentation.

Some of the used experimental designs (e.g. the study of quality of learning (Koukkou & Lehmann, 1968; Lehmann & Koukkou, 1974)) lead to the conclusion that in fact the different brain states, as manifested in the ongoing EEG, are not only the possible consequences, or concomitants of the brain's data processing. Rather the momentary functional brain state which is observable in the ongoing EEG may be concluded to determine the processing strategies and storage spaces which are functionally available to the brain at the moment. This would mean that the momentary class of ongoing EEG activity which reflects the brain's functional state is an indicator of the fate of the information in the brain.

The model of the functional significance of sleep and dreaming

At this point it is of interest to shortly focus on the why these findings were firstly used to discuss dreaming and the use of dreams in psychoanalysis. Discussing the results of our studies on EEG correlates of information processing during sleep,

of day dreaming, and of hypnagogic hallucinations with colleagues working as psychoanalysts in Athens and in Zurich, we were asked: "What can be the contribution of such findings for understanding the functional significance of sleep and dreaming, the why we sleep, the why we dream, and why we forget our dreams so easily. And finally, what can be said on the basis of such empirical findings for Freud's proposal that sleep is the royal road to the unconscious.

The results of our EEG studies together with the at this time available evidence from studies in electrophysiology, psychopharmacology, on brain functions established in experimental psychology, in studies of development, behavior, and state-dependent learning and retrieval were used to write the papers on sleep and dreaming (Koukkou & Lehmann, 1980b, 1983a, 1983b).

Considering the functional significance of sleep and dreaming, we read in the summary (Koukkou & Lehmann, 1983a): The different brain functional states during sleep and wakefulness are associated with differences in processing strategies, memory stores and EEG patterns. Shifts of functional states occur spontaneously or as orienting reactions to processed information, and cause the formal characteristics of dreams. Forgetting of dreams is a function of the magnitude of the difference between states during storage and recall. Based on EEG similarities between sleep stages and developmental stages, brain states during sleep in adults are proposed to correspond functionally with waking states during childhood. Repeated functional regressions occur during sleep, with access to earlier memory material and cognitive strategies unavailable during waking life, so that earlier experiences can be used for current problems. This dream work constitutes the biological significance of sleep and dreaming.

Our model does not postulate dream-specific processes, but use mentation during sleep as a subset of mentation classes which occur during different functional states of the brain.

In our paper in the book edited by W.R. Minzel and W. Herff (Koukkou & Lehmann, 1983b), we discuss the application of such models for discussing the therapeutic effect of dream interpretation in psychotherapy. There it is written: Employing the concept of different functional general states of the brain which suggest that during sleep, mentation of human adults have repeated access to memory material and cognitive strategies of earlier developmental stages. We proposed that: this access permit assessment of new experiences in the light of previous experiences and cognitive strategies (and vice versa), and might constitute the physiological basis of the biological significance of sleep mentation (recalled as dreams) and thus of sleep. One of the important mechanisms in psychoanalytic therapy is the recall of the memory of these developmental stages during which neurotic behavior was developed. In this context neurotic behavior, although undesirable by the individual has become automatized and thus is executed without conscious decisions. The aim of analytic therapy is the reconstruction of this behavior according to present needs and realities of the individual. This aim is reached via the recognition of the neurotic behavior and of the conditions of its origin. Our model proposed how this can be done by working with dreams.

In the two summer schools of the European training program on brain and behavior research which we organized during the seventies in Greece and in the book resulted from the contributions of the invited speakers with the title "Functional states of the brain, their determinants" (Koukkou, Lehmann, & Angst, 1980), we summarized in the

preface: “This book offers a discussion of factors which determine normal and pathological functional states of the brain. The treatment of these global aspects of brain activity – the momentary functional state of the brain – from the viewpoint of different disciplines and utilizing different techniques should orient our work on behavior (of its structural and functional basis) into an improved perspective which considers results and thoughts in neighboring fields. In this way, we can derive some enrichment from looking over the fences of specialization. The concentration on determinants of functional brain state is the book’s pivoting point for communication between specialists. In this book, we participated with three articles.

First, “Brain Functional states: determinants, constraints, and implications” (Koukkou & Lehmann, 1980a). In this article, the theoretical background of the existing literature at that time is summarized in a model of the functional states of the brain. There, it is proposed that the functional states of the brain can be an integration point for the ordering and improved understanding of the phenomena which are related to the brain’s activity during development and different stages of wakefulness and sleep as well as from behavior to subjective internal aspects such as emotions and consciousness.

Second, “Fluctuations of functional states: EEG patterns and perceptual and cognitive strategies” (Lehmann, 1980). In this chapter of Dietrich Lehmann, a review of the evidence for the hypothesis that there is a reliable correspondence between patterns of ongoing scalp EEG activity and type of information processing in the human brain as common manifestations of different functional brain states is presented.

Third, “EEG reactivity in acute schizophrenics reflect deviant (ectropic) state changes during in-

formation processing” (Koukkou, 1980). In the chapter by Koukkou, the use of the concepts of information processing in psychopathology and the use of the EEG correlates of these processes in healthy controls for the investigation and discussion of the form of EEG reactivity to stimuli in acute, drug-free, first-manifestation schizophrenics is discussed.

The concept of EEG manifested brain-functional states with state-dependent information processing: from global brain states to microstates

Parallel to the search for correlations between the conventional EEG records and different reports of the subjects’ subjective experiences, there were efforts from Dietrich Lehmann and his co-workers to develop multi-channel recordings and to review the scalp field as series of maps, as scalp-field-landscapes. These efforts resulted to the use of mapping for the analysis and interpretation of EEG / evoked potential maps (Lehmann & Skrandies, 1979, 1984; Lehmann, Ozaki, & Pal, 1987; Skrandies, 1987; Lehmann, 1989) and to parse the map series with their non-continuous changes with time to a sequence of quasi-stable map landscapes into microstates (e.g. Lehmann, 1971, 1975; Lehmann & Skrandies, 1979, 1984; Lehmann et al., 1987; Skrandies, 1987; Brandeis & Lehmann, 1989; Lehmann, 1989; Lehmann, Strik, Henggeler, Koenig, & Koukkou, 1998; Michel et al., 2001; Skrandies, 2002; Gianotti et al., 2008; Faber, Lehmann, Milz, Travis, & Parim, 2014; Milz et al., submitted). The most recent publications in the field are (Faber et al., 2014), and (Milz et al., submitted).

The concept of EEG manifested brain functional states with state-dependent information processing: a synopsis

The momentary functional state constrains and shapes the elaboration of and the response to newly arriving information and constrains and shapes access within the brain to information processing strategies and to context information which was stored earlier (state-dependent learning and recall).

Classical examples are wakefulness and sleep, or childhood and adulthood, with their different modes of information processing. These gross functional states ought to be seen as composed of local and temporal microstates. A global brain state is thus made up from a large number of local, momentary states of the various cortical functional analyzers and processors. Concerning the temporal dimension, there is good evidence, that as a consequence of newly arriving information, series of different, brief brain states are initiated which manifest different steps and aspects of the processing of the information, and which are referred to as “components” in evoked potential and event-related potential work.

Likewise “spontaneous EEG activity” is hypothesized to consist of a sequence of similarly brief epochs of stationary spatial electric patterns (maps) which manifest different functional states. It is proposed that the spontaneous EEG activity consists of a sequence of similarly brief epochs of stationary spatial electric patterns (maps) which manifest different functional states. Examination of the series of such momentary maps, revealed that the maps’ landscapes change in a non-continuous manner. Accordingly, the map series can be parsed into temporal segments of quasi-

stable map landscapes into microstates. The EEG microstate duration and syntax is studied from the 80s to today in different experimental designs by Lehmann and his coworkers.

References

- Brandeis, D., & Lehmann, D. (1989). Segments of event-related potential map series reveal landscape changes with visual attention and subjective contours. *Electroencephalography and clinical neurophysiology*, 73(6), 507–519.
- Faber, P., Lehmann, D., Milz, P., Travis, F., & Parim, N. (2014). Eeg microstates differ between transcending and mind wandering. In (pp. 53–54). Zürich. (Abstract booklet)
- Gianotti, L. R., Faber, P. L., Schuler, M., Pascual-Marqui, R. D., Kochi, K., & Lehmann, D. (2008). First valence, then arousal: the temporal dynamics of brain electric activity evoked by emotional stimuli. *Brain topography*, 20(3), 143–156.
- Koukkou, M. (1980). EEG reactivity in acute schizophrenics reflects deviant (ectropic) state changes during information processing. In M. Koukkou, D. Lehmann, & J. Angst (Eds.), *Functional States of the Brain: Their Determinants* (pp. 265–290). Amsterdam: Elsevier-North-Holland Biomedical Press.
- Koukkou, M., Dittrich, A., & Lehmann, D. (1975). Hypnagogic experiences and EEG: Assessment by post-awakening questionnaire. *Sleep Research*, 4, 169.
- Koukkou, M., & Lehmann, D. (1968). EEG and memory storage in sleep experiments with humans. *Electroencephalography and clinical neurophysiology*, 25(5), 455–462.
- Koukkou, M., & Lehmann, D. (1976). Human EEG spectra before and during cannabis

- hallucinations. *Biological psychiatry*, 11(6), 663–677.
- Koukkou, M., & Lehmann, D. (1980a). Brain functional states: determinants, constraints, and implications. In M. Koukkou, D. Lehmann, & J. Angst (Eds.), *Functional States of the Brain: Their Determinants* (pp. 13–20). Amsterdam: Elsevier-North-Holland Biomedical Press.
- Koukkou, M., & Lehmann, D. (1980b). Psychophysiologie des Träumens und der Neurosen: Das Zustands-Wechsel-Modell, eine Synops. *Fortschritte der Neurologie: Psychiatrie*, 48(06), 324–350.
- Koukkou, M., & Lehmann, D. (1983a). Dreaming: The functional state-shift hypothesis. A neuropsychophysiological model. *The British Journal of Psychiatry*, 142(3), 221–231.
- Koukkou, M., & Lehmann, D. (1983b). A psychophysiological model of dreaming with implications for the therapeutic effect of dream interpretation. In W. R. Minsal & W. Herff (Eds.), *Research in psychotherapeutic approaches* (Vol. 2, pp. 27–34). Frankfurt am Main: Peter Lang.
- Koukkou, M., Lehmann, D., & Angst, J. (Eds.). (1980). *Functional States of the Brain: Their Determinants*. Elsevier-North-Holland Biomedical Press.
- Lehmann, D. (1971). Multichannel topography of human alpha EEG fields. *Electroencephalography and clinical neurophysiology*, 31(5), 439–449.
- Lehmann, D. (1975). EEG phase differences and their physiological significance in scalp field studies. In G. Dolce (Ed.), *Computerized EEG analysis* (pp. 102–110). Stuttgart: Fischer.
- Lehmann, D. (1980). Fluctuation of functional state: EEG patterns, and perceptual and cognitive strategies. In M. Koukkou, D. Lehmann, & J. Angst (Eds.), *Functional States of the Brain: Their Determinants* (pp. 189–202). Amsterdam: Elsevier-North-Holland Biomedical Press.
- Lehmann, D. (1989). From mapping to the analysis and interpretation of EEG/EP maps. In *Topographic brain mapping of EEG and evoked potentials* (pp. 53–75). Springer.
- Lehmann, D., & Koukkou, M. (1974). Computer analysis of EEG wakefulness-sleep patterns during learning of novel and familiar sentences. *Electroencephalography and Clinical Neurophysiology*, 37(1), 73–84.
- Lehmann, D., & Koukkou, M. (1980). Classes of spontaneous, private experiences and human background EEG. In G. Pfurtscheller (Ed.), *Event-related rhythmic cortical activities; behavioral correlates* (pp. 289–297). Amsterdam: Elsevier.
- Lehmann, D., Koukkou, M., & Andreae, A. (1981). Classes of day-dream mentation and EEG power spectra. *Sleep Research*, 10, 152.
- Lehmann, D., Ozaki, H., & Pal, I. (1987). EEG alpha map series: brain micro-states by space-oriented adaptive segmentation. *Electroencephalography and clinical neurophysiology*, 67(3), 271–288.
- Lehmann, D., & Skrandies, W. (1979). Multichannel mapping of spatial distributions of scalp potential fields evoked by checkerboard reversal to different retinal areas. In *Human Evoked Potentials* (pp. 201–214). Springer.
- Lehmann, D., & Skrandies, W. (1984). Spatial analysis of evoked potentials in man – an overview. *Progress in Neurobiology*, 23, 227–250.
- Lehmann, D., Strik, W., Henggeler, B., Koenig, T., & Koukkou, M. (1998). Brain electric mi-

crostates and momentary conscious mind states as building blocks of spontaneous thinking: I. visual imagery and abstract thoughts. *International Journal of Psychophysiology*, 29(1), 1–11.

Michel, C. M., Thut, G., Morand, S., Khateb, A., Pegna, A. J., de Peralta, R. G., ... Landis, T. (2001). Electric source imaging of human brain functions. *Brain Research Reviews*, 36(2), 108–118.

Milz, P., Faber, P. L., Lehmann, D., Koenig, T., Kochi, K., & Pascual-Marqui, R. D. (submitted). The functional significance of EEG microstates – associations with modalities of thinking.

Skrandies, W. (1987). The upper and lower visual field of man: Electrophysiological and functional differences. *Progress in sensory physiology*, 8.

Skrandies, W. (2002). The Encyclopedia of Imaging Science and Technology. In J. P. Hornak (Ed.), (pp. 198–210). New York: Wiley.

Abstracts of the 23rd German EEG/EP Mapping Meeting, Giessen, October 24-26, 2014

Dietrich Lehmann: From Multichannel EEG Data to Global Field Power to Microstates

W. Skrandies *Physiologisches Institut, Justus-Liebig-Universität Gießen* Dietrich Lehmann had been an active researcher in the field of human neurophysiology and psychophysiology. In the late 1960s he was one of the first to introduce multichannel recordings to electroencephalography. In this presentation a few highlights of the analysis of topographical recordings of EEG and evoked or event-related brain activity will be presented. Electrophysiological brain mapping in itself does not constitute data analysis. Quantitative methods are needed in order to reveal underlying structures in the recorded data. This is a prerequisite that allows direct statistical comparisons between experimental conditions or subject/patient populations. With the first multichannel EEG recordings we were overwhelmed with the amount of electrophysiological data, and methods were needed for data reduction and analysis. Maps depicting brain activity give information on processing time (e.g., latencies in evoked or event-related brain activity), strength, and topography. One of the key concepts is the so-called Global Field Power (GFP) which was introduced in order to identify times of large activity, and for evoked and event-related activity GFP was employed for the definition of components. Commonly, the potential field distributions are simple and can be reduced to few basic configurations. It was at early times that Dietrich Lehmann discov-

ered that sequences of brain activity are composed of a small number of components that were subsequently termed “microstates”. Such “microstates” are interpreted as atoms of thought since they appear consistently in different conditions and subjects.

New methodology for forward and inverse problem in EEG/MEG source analysis and in brain stimulation

C. H. Wolters *Institut für Biomagnetismus und Biosignalanalyse, Westfälische Wilhelms-Universität, Münster* In Electro- (EEG) and Magnetoencephalography (MEG) source analysis, the accuracy of the inverse problem strongly depends on the accuracy of the forward problem. For the forward problem, numerical approaches are needed to compute head surface field distributions from dipolar current sources in the human brain using realistic head volume conductor models derived from MRI sequences. For the forward problem, we will compare standard Lagrange and discontinuous Galerkin finite element methods and validate the approaches in multi-layer sphere models, where quasi-analytical solutions exist. It will be shown that, using Helmholtz reciprocity, these methods can also be used for sensor optimization in brain stimulation using transcranial current stimulation or transcranial magnetic stimulation. For the EEG/MEG inverse problem, hierarchical Bayesian modeling (HBM) emerged as a unifying framework for current density reconstruction (CDR) approaches comprising most established methods as well

as offering promising new methods. We will examine the performance of fully-Bayesian inference methods for HBM for source configurations consisting of few, focal sources when used with realistic head models. The main foci of interest will be the correct depth localization, a well-known source of systematic error of many CDR methods, and the separation of single sources in multiple-source scenarios. For these tasks, HBM provides a promising framework and is able to improve upon established CDR methods such as minimum norm estimation or sLORETA in many aspects. For challenging multiple-source scenarios where the established methods show crucial errors, promising results are attained with HBM. Additionally, we introduce Wasserstein distances as performance measures for the validation of inverse methods in complex source scenarios. We then show how the complementary information in EEG and MEG data stabilizes HBM inverse results. Finally, we present a successful application of our new HBM approaches to combined somatosensory and auditory evoked potentials and fields.

A guideline for volume conductor modeling in EEG and MEG source analysis J. Vorwerk (1), J.-H. Cho (2), S. Rampp (3), H. Hamer (3), T. Knösche (2), C.H. Wolters (1) (1) *Institut für Biomagnetismus und Biosignalanalyse, Westfälische Wilhelms-Universität, Münster*, (2) *Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig*, (3) *Epilepsiezentrum, Universitätsklinikum Erlangen, Erlangen* For accurate results in EEG/MEG source analysis it is necessary to model the head volume conductor as realistic as possible. Here, the distinction of the different conductive compartments in the human head plays an important role. However, every additional compartment that is distinguished

increases the complexity of the model generation. Therefore, we investigated the influence of modeling/not modeling the conductive compartments skull spongiosa, skull compacta, cerebrospinal fluid (CSF), gray matter, white matter, and of the inclusion of white matter anisotropy on the EEG/MEG forward solution. For each of these compartments, we measured the effect on both signal topography and magnitude. By comprehensively evaluating these results, we identified the most important refinement steps in head volume conductor modeling. We were able to show that the inclusion of the highly conductive CSF compartment and of gray/white matter distinction have the strongest influence on both signal topography and magnitude in EEG and MEG. For both of these steps the effects showed a clear spatial pattern. In comparison to these two steps, the introduction of white matter anisotropy led to a clearly weaker, but still strong, effect. Finally, the distinction between skull spongiosa and compacta caused the weakest effects when already using an optimized conductivity value for the homogenized skull compartment. We conclude that it is highly recommendable to include the CSF and distinguish between gray and white matter in head volume conductor modeling, while, especially for the MEG, the modeling of skull spongiosa and compacta might be neglected due to the weak effects. The simplification of not modeling white matter anisotropy is admissible considering the complexity and current limitations of the underlying modeling approach.

This research was supported by the German Research Foundation (DFG) through project WO1425/2-1, STE380/14-1, KN588/4-1 and by the Priority Program 1665 of the DFG (project WO1425/5-1).

Sensitivity of connectivity measures to inaccuracies in forward and inverse EEG/MEG modeling

T.R. Knösche (1), J.H. Cho (1), J. Vorwerk (2), C.H. Wolters (2) (1) *Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig*, (2) *Institut für Biomagnetismus und Biosignalanalyse, Westfälische Wilhelms-Universität, Münster* The results of brain connectivity analysis using reconstructed source time courses derived from EEG and MEG data depend on a number of algorithmic choices. While previous studies have investigated the influence of the choice of source estimation method or connectivity measure, the effects of the head modeling errors or simplifications have not been studied sufficiently. In the present simulation study, we investigated the influence of particular properties of the head model on the reconstructed source time courses as well as on source connectivity analysis in EEG and MEG. Therefore, we constructed a realistic head model and applied the finite element method to solve the EEG and MEG forward problem. We considered the distinction between white and gray matter, the distinction between compact and spongy bone, the inclusion of a cerebrospinal fluid (CSF) compartment, and the reduction to a simple 3-layer model comprising only skin, skull, and brain. Source time courses were reconstructed using a beamforming approach and the source connectivity was estimated by the imaginary coherence (ICoh) and the generalized partial directed coherence (GPDC).

Combined EEG/MEG can outperform single modality EEG or MEG source analysis in presurgical epilepsy diagnosis

Ü. Aydın (1,2), J. Vorwerk (1), M. Dümpelmann (3), M. Heers (3), P. Küpper (4), H. Kugel (5), J. Wellmer (6), C. Kellinghaus (4), J. Haueisen (2), S. Rampp (7), H. Stefan (7), C.H. Wol-

ters (1) (1) *Institute for Biomagnetism and Biosignalanalysis, Westfälische Wilhelms-Universität Münster*, (2) *Institute of Biomedical Engineering and Informatics, Technische Universität Ilmenau*, (3) *Epilepsy Center, Universitäts-klinikum Freiburg*, (4) *Department of Neurology, Klinikum Osnabrück*, (5) *Department of Clinical Radiology, Universitäts-klinikum Münster*, (6) *Ruhr-Epileptology Department of Neurology, Universitätsklinikum Knappschaftskrankenhaus Bochum*, (7) *Epilepsy Center, Department of Neurology, Universitäts-klinikum Erlangen* Epileptiform activity might have already been subject to propagation at the peak of the spike. Therefore, in order to determine the origin of the spike, source reconstruction should be performed close to spike onset, i.e., as early in time as possible. However, usually the low signal-to-noise-ratio (SNR) at the spike onset limits the precision of noninvasive source reconstructions. In this study we compared the performances of single modality EEG, MEG and combined EEG/MEG (EMEG) source reconstructions in revealing the spike origin and the propagation pathway. For this purpose, we used simultaneous EEG and MEG measurements from a patient suffering from pharmaco-resistant focal epilepsy and accepted the findings of simultaneously measured low density EEG and stereo-EEG (sEEG) as the ground-truth. In order to consider different sensitivity profiles of EEG and MEG, a detailed six-compartment finite element head model that comprises anisotropic white matter conductivity derived from diffusion tensor MRI, and skull conductivity calibrated via somatosensory evoked responses was constructed. Location and extent of the irritative zone were estimated by dipole scans calculated for multiple subaverages. Our results showed that unlike EEG and MEG alone, EMEG localizations at the spike onset were

stable and in agreement with the left temporomesial origin determined via sEEG. At later instants in time, activity measured by sEEG propagated to lateral parts and to the pole of the temporal lobe. Although EMEG localizations were able to reveal this entire pathway, EEG or MEG alone was able to reconstruct only parts of it. Our results thus confirm our hypothesis that the complementary information of EEG and MEG enables accurate EMEG localizations even for low SNR schemes such as the spike onset.

This study was supported by DFG projects WO1425/2-1 and STE380/14-1, the Priority Program 1665 of the DFG (project WO1425/5-1), and Ruhr University Bochum (K062-11).

Slow waves and fast oscillations – Epilepsy in the frequency domain S. Rampp *Neurologische Universitätsklinik, Epilepsiezentrum, Uniklinik Erlangen* In recent years, novel markers of epilepsy beyond interictal spike and sharp waves and ictal seizure correlates have been described. Fast activity, from high gamma oscillations to ripples and fast ripples may represent surrogates of epileptic pathomechanisms. Especially the faster subtypes show high specificity for the epileptogenic zone. Detection is possible using mainly invasive recordings, however recent advances may offer methods for non-invasive evaluation. Slow wave and infra slow activity at the other end of the frequency spectrum are detected using both invasive and non-invasive means. While their existence has been known for many years, novel techniques now enable detailed analysis and use for epileptic focus localization. The presentation will give an overview on the frequency domain perspective on epilepsy. Current methods and clinical applications using MEG, as well as surface and invasive EEG are presented and illustrated with case examples.

Sensitivity of MEG to hippocampal activity: Evidence from combined MEG-intracranial EEG investigations

S.S. Dalal, M. Crespo-García, K. Jerbi, A. Ducorps, D. Schwartz, J.-P. Lachaux, H. Hamer, S. Rampp *FB Psychologie & Zukunftskolleg, Universität Konstanz* Cognition, memory, and perceptual processes are all facilitated by the electrical activity of various brain structures. The faint signatures of this activity can be detected with both EEG and MEG, with most research aiming to resolve activity near the brain surface. However, neural processing inevitably involves deeper brain structures such as the hippocampus, which plays important roles in memory encoding and spatial navigation, and is furthermore often implicated in epilepsy. Intracranial EEG can allow reliable detection of the hippocampus in certain patient populations. However, only noninvasive EEG and MEG can provide a “whole brain” view of neural dynamics. More accurate representation of recording parameters as well as realistic head models may facilitate the detection of weaker brain signals, and by extension, deeper brain sources. In our experiments, depth EEG from the hippocampus demonstrated relatively strong correlation at zero-lag with patches of MEG sensors, often forming dipolar correlation patterns when visualized as a scalp topography. However, these topographies were more complex than the overlapping spheres model often used for MEG forward modeling. Our results suggest that source reconstruction techniques such as beamforming, when combined with realistic head models, increase the effective SNR of MEG data. In this manner, it enables the detection of weaker signals, including those arising from deeper sources such as the hippocampus.

Reconstruction of EEG-data using radial basis functions

J. Jäger (1), M. Buhmann (1), A. Klein (2), W. Skrandies (2) (1) *Institut für numerische Mathematik, Justus-Liebig-Universität Gießen*, (2) *Physiologisches Institut, Justus-Liebig-Universität Gießen* The reconstruction of data by interpolation methods is of practical interest in EEG research as it is a basis for brain-mapping of multichannel data. In addition, interpolation algorithms can be used for the reconstruction of missing data due to technical problems (e.g., caused by a broken electrode). Methods stemming from approximation theory have been applied to this, yet several problems remain. In the present contribution we investigate whether the application of radial basis functions has advantages as compared to the commonly used nearest neighbor and spherical-splines methods. In addition, we were interested in whether the radial basis functions are easier to calculate. Radial basis functions are used in many areas, and good results have been achieved especially when the approximation of sphere-like surfaces was investigated. A radial basis function is a real-valued function whose value depends solely on its distance to the origin. For interpolation, one uses radial basis functions whose value depends on the distance between a given data point and the evaluation point. A sum of those radial basis functions is then used to approximate the unknown brain potential value. A significant advantage of radial basis functions is the fact that an interpolation is always possible, independent of the number of data points and their distribution. We applied this method to various sets of 64-channel EEG data, and evaluated computation time and accuracy of the reconstructed signal. We will show that the interpolation with

multiquadric radial basis functions is superior to other interpolation methods.

Assessing changes of brain connectivity patterns related to learning Kanji characters by combining parallel factor analysis and partial directed coherence

B. Pester (1), K. Schiecke (1), A. Klein (2), H. Witte (1), W. Skrandies (2) (1) *Institut für medizinische Statistik, Informatik und Dokumentation, Universitätsklinikum Friedrich-Schiller-Universität, Jena*, (2) *Physiologisches Institut, Justus-Liebig-Universität, Gießen* Semantic learning of Kanji characters has been proven to cause topographical changes in electrical brain activity. The objective of this work is to answer the question whether these changes in activity are accompanied by changes in connectivity. A well-established measure of effective connectivity in complex brain networks is provided by time-variant partial directed coherence (tvPDC) based on time-variant multivariate autoregressive processes. Due to its time- and frequency-selectivity, this approach enables a proper examination of signals which are temporally variable and where relevant interactions are supposed to comprise only limited frequency ranges. However, this advantage is the source of a massive amount of results, causing serious problems in interpretability. A way to solve this problem is a decomposition of the three-way tvPDC results into a trilinear tensor product by means of parallel factor analysis. This leads to a data condensation which allows an easier overall evaluation of the results and can help to uncover inherent interaction patterns. We apply this methodology to EEG data of a study investigating ERPs aroused by reading Kanji characters. The experimental protocol was separated into three parts: first, EEG was recorded during the presentation

of Kanji symbols as well as control stimuli to probands not being familiar with the symbol meaning. After a learning period of 20 minutes the recording step was repeated. Stimulus condition (target/control) and learning condition (pre learning/post learning) were analyzed separately. To better understand the effect of Kanji learning, we additionally calculated the test statistic of a paired t-test of tvPDC results (target stimulus before learning vs. target stimulus after learning; subject-individual results served as realizations of the random variables) and performed tensor decomposition to the resultant t-values.

Nichtparametrische statistische Analyse von Potential- und Quellverteilungen auf Epochen-Ebenen

M. Wagner, C. Ponton, R. Tech, M. Fuchs, J. Kastner *Compumedics Neuroscan, Hamburg* In Event-Related Potential and Event-Related Field experiments, stimuli — often of several different types — are presented repeatedly, and the subject's brain response is recorded using Electroencephalography (EEG) or, in the ERF case, Magnetoencephalography (MEG). After removing artifacts and epoching the data, many repetitions per stimulus type are available, which are later usually averaged and compared. At this stage, though, it is no longer possible to establish whether and for which latencies the averaged waveforms are significantly different between stimulus types, nor whether the epochs for a given stimulus type yield significant averages in the first place. A statistical analysis of all individual epochs can provide exactly this information. Topographic Analysis of Variance (TANOVA) and Statistical non-Parametric Mapping performed on the results of Current Density Reconstructions (CDR SnPM) are non-parametric permutation or randomization tests which have previously been published but mainly

been used to process per-subject averaged EEG data in the context of group studies. This paper describes how to apply TANOVA and CDR SnPM to individual epochs on a sample-by-sample basis, even in the context of single-subject data. A multiple comparison correction approach for the analysis of subsequent samples based on spectral properties of the data is presented. Methods are demonstrated using filtered and unfiltered simulated dipole data and data from a Continuous Performance Task (CPT) EEG experiment eliciting Mismatch Negativity. While TANOVA is able to identify latencies of significantly different map topographies, CDR SnPM extracts — per latency — the locations of significant source activation differences between stimulus types, albeit at the price of reduced overall sensitivity. Using simulated data, the proposed multiple comparison correction approach is illustrated. Significant peaks and source locations obtained for the CPT data are consistent with existing knowledge.

Einfluss multivariater Granger-Kausalität mit eingebundener Dimensionsreduktion auf Netzwerkcommunities

C. Schmidt, B. Pester, M. Nagarajan H. Witte, L. Leistritz, A. Wismueller *Institut für medizinische Statistik, Informatik und Dokumentation, Universitätsklinikum Friedrich-Schiller-Universität, Jena* High dimensional functional MRI data in combination with a low temporal resolution imposes computational limits on classical Granger Causality analyses with respect to a large-scale representations of functional interactions in the brain. To overcome these limitations and exploit information inherent in resulting brain connectivity networks at the large scale, we propose a multivariate Granger Causality approach with embedded dimension reduction. Using this approach, we computed binary connectivity networks from resting state

fMRI images and analyzed them with respect to network module structure, which might be linked to distinct brain regions with an increased density of particular interaction patterns as compared to inter-module regions. As a proof of concept, we show that the modular structure of these large-scale connectivity networks can be recovered. These results are promising since further analysis of large-scale brain network partitions into modules might prove valuable for understanding and tracing changes in brain connectivity at a more detailed resolution level than before.

Amplitude, Topographie und Latenz von EKP-Komponenten analysiert mit Hilfe von Randomisierungsstatistiken: Ein anwendungsorientierter Ragu-Workshop Th. Koenig (1), M. Kottlow (1,2) (1) *Abteilung für psychiatrische Neuropsychologie, Universitätsklinik für Psychiatrie, Universität Bern, Schweiz,* (2) *Institut für Pharmakologie und Toxikologie, Universität Zürich, Schweiz*

Bei EKP-Experimenten ist oft nicht von vornherein klar, in welchen Zeitfenstern Effekte erwartet werden. Daher müssen Analysen die Daten über mehrere Zeitfenster hinweg explorieren. Darüber hinaus sind statistische Analysen, die alle Elektroden berücksichtigen, wünschenswert, aber nicht trivial. Zur Lösung dieser Probleme präsentieren wir hier das Programm Ragu (Randomization Graphical User interface), das spezifisch für die statistische Auswertung von Mehrkanal EEG-Experimenten eingesetzt werden kann. Ragu soll Wissenschaftlern die Möglichkeit geben, die Signifikanzen von EKP-Effekten global zu untersuchen, ohne die Notwendigkeit von A-Priori-Annahmen. Das Programm basiert auf der Messung von Topografie-Differenzen unter Berücksichtigung aller Elektroden. Im ersten Teil dieses Workshops werden wir die Notwendigkeit von to-

pografischen ERP-Analysen angesichts des Volumenleitungsproblems herausarbeiten und Vergleiche zu Einzelelektroden-Ansätzen anstellen. Wir werden anhand unserer frei erhältlichen Software Ragu das Prinzip von Randomisierungsstatistiken erklären und deren unterschiedliche Anwendungsmöglichkeiten für ERP-Analysen. In einem zweiten Teil haben die Teilnehmenden die Gelegenheit, Ragu an einem Beispielsatz auszuprobieren und Möglichkeiten der Anwendung von Ragu in ihrer eigenen Forschung zu besprechen.

Bewegungslernen durch Spiegeltraining und der Einfluss auf EEG-Parameter V. Kapser,

M. Doppelmayr *Abteilung Sportpsychologie, Institut Sportwissenschaft, Universität Mainz* Spiegeltraining (mirror training) ist ein Konzept zum Erlernen einer Bewegung und wurde ursprünglich zur Behandlung von Phantomschmerzen eingesetzt. Aktuelle Studien untermauern die Effektivität beim Wiedererlernen von Bewegungen nach Schlaganfällen. Beim Spiegeltraining wird eine Bewegung mit z.B. der rechten Hand ausgeführt und die betreffende Person sieht diese Bewegung über einen Spiegel. Das führt zur Empfindung die linke Hand würde diese Bewegung ausführen. Durch diese Art des Trainings kommt es zu Transfereffekten und auch die eigentlich untrainierte (linke) Hand verbessert ihre Leistung. Im Rahmen der aktuellen Pilotstudie wird dieser Transfereffekt anhand von 21 Versuchspersonen mittels Elektroenzephalogramm (EEG) untersucht. Jede Versuchsperson rotierte während des Trainings 2 kleine Gummibälle in der rechten Hand für die Dauer von jeweils 15 Minuten. Dies wurde an 5 Tagen wiederholt wobei an Tag 1 und an Tag 5 das EEG aufgezeichnet wurde. Gruppe 1 (Spiegelgruppe, n=7) betrachtete dabei das Spiegelbild der rechten Hand, was das Gefühl hervorruft, die linke Hand würde die Bälle rotieren. Grup-

pe 2 (Ruhegruppe n=7) betrachtete während der Rotationen die linke, ruhig auf dem Tisch liegenden, Hand. Gruppe 3 (Bewegungsgruppe, n=7) trainierte die Rotationen parallel in beiden Händen und beobachtete die linke Hand, welche die Bewegung tatsächlich, symmetrisch zur rechten Hand, ausführte. Vor und nach dem Training wurde die Rotationsleistung der linken Hand erhoben. Im Gegensatz zu aktuellen Befunden zeigte eine zweifaktorielle ANOVA mit den Faktoren GRUPE und TIME lediglich eine signifikante Verbesserung durch das Training, aber keine Gruppenunterschiede. Im Rahmen der Präsentation dieser ersten Daten wird auf die den Lernvorgängen zugehörigen EEG Parameter wie Amplitudenveränderungen des bewegungssensitiven mu-Rhythmus im Vergleich zwischen den motorischen Arealen der beiden Hemisphären eingegangen.

Effekte von tDCS auf das Erlernen einfacher visuo-motorischer Aufgaben

M. Doppelmayr, N. Pixa, F. Meud *Institut für Sportwissenschaft, Universität Mainz* Aim of the presented pilot-study is to investigate the effects of transcranial direct current stimulation (tDCS, Starstim, Neuroelectronics) on motor adaption in a mirror drawing task. Participants (n=39, age M=24.44; SD=1.62) were randomly assigned to one of three different training groups. All groups performed the following tasks. Subjects were seated in front of a mirror and different geometrical figures were presented in a way that these figures were only visible via the mirror. The task was to learn how to follow the lines with a pen, held in the right hand, as fast and correct as possible. Beside a pre and a posttest the subjects had to perform this task for 20 minutes, while stimulated with tDC. Additionally a follow up test was performed 20 minutes after the posttest. During training subjects received anodal tDCS at either cerebel-

lar (CER) or right parietal (PAR) location (P4) or received a sham stimulation (CG). 1mA with a ramp up/down of 30 seconds with pi-electrodes (3.14cm²) was applied for 23 minutes and multiple return sites were used. Analyzing the speed of the drawing a two-way ANOVA TIME (Pre, Training, Post, Follow up) and GROUP (CER, PAR, CG) revealed significant ($p < 0.05$) effects for TIME and GROUP as well as a significant interaction. CER showed the shortest and CG the longest drawing times with increasing group differences with TIME. For drawing quality a similar result emerged. Again both main effects as well as the interaction reached significance. The number of drawing errors was lowest in the CER group and highest in the CG and again differences increased with TIME. Taken together the data indicate that tDCS can be effective in increasing the learning process for small hand movements. Further research is needed to disentangle cognitive and motor aspects of these results.

Kortikale Prozesse während der „first-trial“ Reaktion bei transienten Gleichgewichtsaufgaben

T. Hülsdünker (1), A. Mierau (1), H. Kleinöder (2), H.K. Strüder (1) (1) *Institute of Movement and Neurosciences, German Sport University Cologne, Cologne*, (2) *Institute of Training Science and Sport Informatics, German Sport University Cologne, Cologne*

The compensation for a sudden balance perturbation, unpractised and unpredictable in timing and magnitude, the so called first-trial reaction, is accompanied by pronounced postural instability that is suggested to be causal to falls. However, even though it is well established that the cerebral cortex is essentially involved in the control of balance and upright posture, the cortical processes underlying the first-trial reaction are still unknown. Therefore, this study aimed to identify cortical

characteristics during the first-trial reaction that would provide further insights into neural processes associated with falls. 37 subjects were exposed to ten transient balance perturbations induced by a sideward movement of the supporting platform. Cortical activity was recorded using a 32-channel EEG-system. Postural instability was determined by platform movements and EMG activity of the m. peroneus during the first second following perturbation. Amplitude and latency of cortical P1 and N1 potentials were analysed for each trial individually. P1 and N1 potentials were localised by LORETA transformation. P1 and N1 potentials were located in Brodmann Area 5 and 6, respectively. Results on the P1 potential revealed no changes in amplitude or latency over trials. In contrast, first-trial effects were found for N1 amplitude in frontal and parietal electrodes as indicated by a significant decrease in N1 amplitude from trial 1 to trial 2. Furthermore, habituation effects were reflected by a reduction of N1 latency over trials. EMG data indicated a decrease of muscular activity from trial 1 to trial 2 in both legs, accompanied by a reduction of platform movements. It is concluded that first-trial reactions to unpredictable balance perturbations are accompanied by unique characteristics in cortical activity. The P1 is suggested to reflect the initial sensory response to perturbation-induced afferent feedback while the N1 is probably involved in error-detection and -processing.

Kortikaler Informationsfluss während der Kompensation einer Gleichgewichtsstörung

B. Pester (1), A. Mierau (2), T. Hülsdünker (2), H. Witte (1), H.K. Strüder (2) (1) *Institut für medizinische Statistik, Informatik und Dokumentation, Universitäts-klinikum Friedrich-Schiller-Universität, Jena*, (2) *Institute of Movement and Neurosciences, German Sport University Cologne*,

Cologne Balance control is a fundamental human skill required in numerous every day activities and particularly during locomotion. Sudden balance perturbations are associated with marked changes in electrocortical activity suggesting that the cerebral cortex is essentially involved in the control of balance and upright posture. Specifically, we and others have found that theta activity increases in a fronto-centro-parietal network during transient and continuous balance tasks. It has been suggested that fronto-parietal theta oscillations may transmit afferent information from parietal sensory areas to facilitate movement error detection and balance monitoring in the fronto-central cortex. However, this interpretation remains speculative as all previous findings are based on neuronal activity which does not allow immediate conclusions about neuronal information transfer. Therefore, we analyzed EEG data during a balance perturbation task in order to explore the benefits and limitations of connectivity analyses and to investigate whether the paths of information flow as indicated by electrocortical activity can be retrieved. Quantification of interaction strength was implemented by two connectivity measures on the basis of a time-variant multivariate autoregressive (AR) model: time-variant Granger causality index (tvGCI) and time-variant partial directed coherence (tvPDC). For tvGCI calculation, AR model residuals are used, while tvPDC comprises the Fourier transform of the estimated AR parameters. Thus, both measures have different advantages and disadvantages and there are cases where one or even both of them are not appropriate. Furthermore, we investigated the influence of previous artefact rejection by means of independent component analysis (ICA) in this context. On the one hand, EEG data during motion are highly affected by artefacts;

on the other hand, ICA preprocessing can lead to false positive or false negative findings in interaction analysis. This study represents a first step towards understanding neural information transfer during balance control by exploring, comparing and discussing different network measures and the influence of a previous ICA-based artefact rejection.

Lebenslange sportliche Aktivität beeinflusst kognitive Funktionen bei Senioren: Evidenz aus Verhalten und EKPs

P.D. Gajewski, M. Falkenstein *Leibniz Institut für Arbeitsforschung (IfADo), Dortmund* Altern geht mit Beeinträchtigungen kognitiver Prozesse einher. Verschiedene Interventionsstudien zeigen positive Effekte von körperlichem Training auf kognitive Funktionen bei Senioren, wobei sich insbesondere exekutive Funktionen wie Arbeitsgedächtnis, Aufgabenwechsel, und Interferenzverarbeitung verbessern. Allerdings waren die Interventionsdauern in den bisherigen Studien mit 4 bis 18 Monaten relativ kurz. In der vorliegenden Studie wurde der Effekt lebenslanger körperlicher Aktivität auf exekutive Funktionen mit Hilfe von ereigniskorrelierte Potenzialen (EKP) untersucht. Hierzu führten zwei Gruppen (je n=20) langjährig sportlich aktiver vs. passiver Senioren eine Stroop- und eine gedächtnisbasierte Wechselaufgabe durch, wobei das EEG abgeleitet wurde und daraus EKP extrahiert wurden. Bei der Stroop-Aufgabe reagierten die Probanden auf farbige Wortreize, wobei häufig Farbe und Wort inkongruent waren. Bei der Wechsel-Aufgabe wechselten sie nach einer festen Sequenz zwischen drei Aufgaben. Die langjährig sportlich Aktiven zeigten konsistent bessere Leistungen bei beiden exekutiven Aufgaben. In den EKPs zeigte sich in beiden Aufgaben bei den Aktiven eine kürzere Latenz der frontalen P2 und eine protra-

hierte negative Verschiebung an frontozentralen Elektroden. Die Ergebnisse zeigen eine Beschleunigung mehr reizbezogener Verarbeitung (P2) und eine Intensivierung exekutiver Funktionen (frontozentrale Aktivierung). Die EKP-Muster der aktiven Senioren ähneln dabei denen junger Erwachsener. Diese Daten zeigen, dass lebenslange sportliche Aktivität bei Senioren mit einem mehr „jugendlichen“ EKP-Muster einhergeht, wodurch wesentliche kognitive Prozesse und die Leistung bei den Aktiven gegenüber sportlich Inaktiven konsistent verbessert werden.

Auswirkungen körperlicher Aktivität auf die individuelle EEG Alpha Peak Frequenz

A. Mierau, T. Hülsdünker, B. Gutmann, J. Mierau, H.K. Strüder *Institute of Movement and Neurosciences, German Sport University Cologne* The individual alpha peak frequency (iAPF) is thought to represent a neurophysiological marker of the individual's state of arousal and attention. Several studies have shown that high iAPF is associated with improved performance in various cognitive tasks and, on the other hand, cognitive impairment due to neurological diseases is accompanied by a reduction of the iAPF. More recent studies demonstrated that small intraindividual temporal iAPF fluctuations correlate with increased blood oxygenation level-dependent signal in brain areas associated with working memory functions and the modulation of attention. Furthermore, it has been shown that white matter architecture is a key determinant for the iAPF. Although, the iAPF has generated considerable recent research interest, not much is known about its modifiability through interventions. Particularly, it has not been studied so far whether the iAPF is sensitive to motor and/or physical activity. This is surprising given that extensive research in humans suggests that

motor and physical activity have beneficial effects on brain function. We have analyzed the iAPF in a series of different motor and physical activity experiments with healthy subjects. Experiment 1 revealed that the iAPF is increased following a single bout of maximal physical exercise whereas no changes in iAPF were observed after submaximal exercise. Experiment 2 showed that the iAPF increases during tasks requiring control of posture and balance. Finally, as revealed by experiment 3, in young children the iAPF is correlated with gross motor skills, particularly running ability, but not with cognitive task performance. While the first two experiments indicate that motor and physical activity induce transient changes in iAPF, the latter experiment may suggest that the increase in iAPF during childhood brain development is strongly influenced by motor experience.

Influence of stable and changeable aspects of face processing on neural predictors of memory encoding

T. Padovani (1), C. Martarelli (1), D. Bombari (2), Th. Koenig (3), F. Mast (1), W. J. Perrig (1) (1) *Institute of Psychology, University of Bern, Switzerland*, (2) *Department of Work and Organizational Psychology, University of Neuchâtel, Neuchâtel, Switzerland*, (3) *University Hospital of Psychiatry, University of Bern, Switzerland* Effective encoding relies on the neural activity before and after the onset of an event. Recent studies have shown that pre-stimulus activity can predict retrieval success. In the present experiment we investigate how identity and emotional aspects of face processing modulate this preparatory activity. Electrical brain activity was recorded from 35 healthy participants while they were presented with unfamiliar faces. Two types of cues shown immediately before the presentation of the face stimuli indicated what task to

perform: in one condition the cue required an age judgement and in the other condition an emotional judgment. A recognition memory task followed after a break with all the faces presented previously and 1/3 of new facial stimuli. By using the subsequent memory paradigm, our preliminary results suggest that the neural activity preceding the face presentation can be modulated by the nature of the task to be performed and can predict whether the face will be later recognized. Computing normalized TANOVAs (Topographic Analysis of Variance) on the whole pre-stimulus interval will allow us to assess if and at which time point the two tasks – performed during the encoding of faces – involve different generators as predicted by the distributed human neural system for face perception (Haxby et al. 2000). The use of inverse solution analyses will help us to identify the location of these generators. Additionally the estimate of the Global Field Power will further clarify if there are global quantitative differences. These results would further confirm that effective encoding can be modulated by preparatory processes that are task-specific. When these tasks involve stable or changeable aspects of face processing such as age identity or emotional expressions, it would be possible to identify and predict how and when the underlying neural representations differently interact with memory and finally lead to successful recognition of unfamiliar faces.

Neuronale Korrelate des Alterns M. J. Herrmann, V. Huber, L. Müller, M. Lauer, T. Polak *Zentrum für Psychische Gesundheit, Würzburg* Während in jungen Jahren bestimmte kognitive Prozesse stark lateralisiert sind, findet man im Alter häufig eine bilaterale präfrontale Aktivierung. Diese reduzierte Hemisphären-Asymmetrie bei Älteren ist als sog. HAROLD-Muster bekannt und wurde konsistent für eine Vielzahl den

präfrontalen Cortex (PFC) aktivierender Aufgaben nachgewiesen. Hinsichtlich der Funktionalität der reduzierten Hemisphären-Asymmetrie bestehen zwei Erklärungsmodelle: das der Kompensation, das das HAROLD-Muster als funktional, leistungsunterstützend und kompensatorisch ansieht, und das der Dedifferenzierung, das dahinter mehr eine pathologische Begleiterscheinung des Alterns ohne spezielle Funktion vermutet. Ziel dieser Studie war es – für den Bereich der exekutiven und Sprach-Funktionen – einen Beleg für eine der beiden Hypothesen zu erbringen. Hierzu wurden 247 gesunde ältere Probanden zwischen 70 und 76 Jahren mit einer Wortflüssigkeitsaufgabe untersucht, während ihre kortikale Gehirnaktivität mittels funktioneller Nahinfrarotspektroskopie gemessen wurde. Die Stichprobe wurde anhand der Leistung in „high performer“ (n=62) und „low performer“ (n=64) unterteilt. Die Ergebnisse zeigen eine signifikante Zusatzaktivierung im Fronto-Temporalen Kortex in der Gruppe der „high performer“ im Vergleich zur Gruppe der „low performer“, und stützen somit die Annahme einer kompensatorischen Mehraktivierung. Im Dorsolateralen Präfrontalkortex hingegen zeigen sich keine Unterschiede zwischen „high“ und „low performer“, so dass in dieser Region eher von einer Dedifferenzierung auszugehen ist.

Neuronale Korrelate exekutiver Funktionen bei Depression im Alter: Eine NIRS Studie

D. Rosenbaum, A.-C. Ehli, K. Hagen, F. G. Metzger, S. Heinzel, A. J. Fallgatter *Psychophysiology und Optische Bildgebung, Universitätsklinikum Tübingen* Der Zusammenhang zwischen Depression und kognitiven Funktionsdefiziten konnte bereits in zahlreichen Studien nachgewiesen werden. Insbesondere im Alter zeigen sich überzufällig häufig Zusammenhänge zwischen dem Auftreten einer Depression und nachfolgenden kogni-

tiven Einbußen, welche auch nach einer Remission der depressiven Symptomatik weiterhin bestehen bleiben und in demenziellen Erkrankungen münden können. Die vorliegende Studie sollte untersuchen, welche Zusammenhänge zwischen Depression, kognitiven Leistungen und der zerebralen Oxygenierung während einer kognitiven Aufgabe bestanden. Untersucht wurden Veränderungen im Oxy-Hämoglobin (OxyHb) während eines Trail-Making Test (TMT) bei einer gematchten Stichprobe bestehend aus 49 depressiven Probanden und 51 Kontrollpersonen mittels Nahinfrarotspektroskopie (NIRS). Neben Unterschieden im absoluten Anstieg des OxyHb wurden zusätzlich netzwerkbasierte Unterschiede der aufgabenspezifischen funktionalen Konnektivität untersucht. Hypothesenkonform zeigten sich differentielle Unterschiede bezüglich des OxyHb Levels zwischen Depressiven und Nicht-Depressiven Kontrollen. Unterstrichen wurde dieser Effekt durch signifikant unterschiedliche fronto-parietale Netzwerkeigenschaften der depressiven Stichprobe. Die Effekte werden vor dem Hintergrund depressiver Erkrankungen im Alter und deren Relevanz für zerebrale Entwicklungsprozesse diskutiert.

NIRS-Neurofeedback als Behandlungsmethode bei erwachsenen Patienten mit einer Aufmerksamkeitsdefizit-/Hyperaktivitätsstörung (ADHS)

B. Barth (1,2), A.-C. Ehli (1), K. Mayer (3), A. J. Fallgatter (1), U. Strehl (3) (1) *Psychophysiology & Optical Imaging, Psychiatric University Hospital Tübingen*, (2) *Graduate School of Neural & Behavioural Sciences, University of Tübingen*, (3) *Institute of Medical Psychology and Behavioral Neurobiology, University Hospital Tübingen*

Attention-deficit/hyperactivity disorder (ADHD) is one of the most common disorders of childhood. For a high proportion of children, the pri-

mary symptoms, i.e. inattentiveness, impulsivity, and hyperactivity – persist into adulthood. On a functional level, the commonly found hypoactivation of the prefrontal cortex (PFC) has been assumed to underlie many of the deficits observed in ADHD. By means of neurofeedback training patients can learn to regulate prefrontal brain activity to induce a state of cortical activity which is associated with a better allocation of attentional resources and other executive functions. The present study is part of a larger project designed to compare the efficacy of specific biofeedback protocols in changing primary symptoms as well as cognitive and neurophysiological variables in adult ADHD patients. The aim is to evaluate the feasibility of conducting a trial of near-infrared spectroscopy (NIRS)-neurofeedback as a treatment option for adult ADHD patients and compare it to a less specific Electromyography (EMG)-biofeedback training. In NIRS-neurofeedback the up-regulation period is operationalized as an increase in the concentration of oxygenated hemoglobin (O₂Hb) within a predefined region of interest (NIRS channels covering left and right lateral prefrontal areas). During the deactivation period, subjects should achieve a decrease in O₂Hb concentration within the same target region. In EMG-Biofeedback, EMG-electrodes are placed over right and left musculi supraspinatus. To upregulate the signal, participants are asked to tense the right muscle and to relax the left muscle. To downregulate the signal, they have to perform the task vice versa. To examine changes in neurocognitive functions, all participants undergo NIRS measurements while performing cognitive tasks to assess whether the NIRS-neurofeedback training (N=10 out of 20) results in higher normalization of prefrontal (dys)function as compared to the less spe-

cific EMG-biofeedback training (N=6 out of 20). These preliminary data will be presented at the conference.

Neuronale und hämodynamische Marker komplexer Sprachverarbeitung bei Schizophrenie-Patienten: Eine kombinierte fNIRS-EEG-Studie S. Schneider, L. Wagels, F. B. Häußinger, A. M. Rapp, A. J. Fallgatter, A.-C. Ehlis *Klinik für Psychiatrie und Psychotherapie, Abteilung Allgemeine Psychiatrie, Universität Tübingen, Klinik für Psychiatrie, Psychotherapie und Psychosomatik, Universität Aachen*

Aufgrund ihrer physikalischen Eigenschaften eignet sich die Methode der funktionellen Nahinfrarot-Spektroskopie (fNIRS) besonders für kombinierte Anwendungen mit anderen Bildgebungsverfahren, insbesondere der Elektroenzephalographie (EEG). Solche simultanen fNIRS-EEG Messungen sind insbesondere für Untersuchungen kortikaler Sprachverarbeitungsprozesse vorteilhaft, da diese sowohl zeitlich als auch räumlich auflösende Verfahren erfordern. In einer aktuellen Studie wurden kombinierte fNIRS-EEG Messungen zur Erfassung kortikaler Substrate des Verstehens komplexer, nichtwörtlicher Sprache bei Patienten mit Schizophrenie angewendet. Hierbei bearbeiteten 22 Schizophrenie-Patienten und 22 gesunde Kontrollpersonen ein linguistisches Paradigma, bei dem die Sinnhaftigkeit von drei verschiedenen Satztypen (sinnvoll/wörtlich; sinnvoll/metaphorisch; sinnlos) eingeschätzt werden musste. Neben dem im Zusammenhang mit Sprachverarbeitung viel untersuchten N400 ereigniskorrelierten Potential (EKP) wurden hierbei auch erstmals sehr frühe Prozesse der Satz-Verarbeitung (z.B. P200) fokussiert. Zudem sollten die kortikalen hämodynamischen Aktivierungsmuster innerhalb sprach-assoziierten Areale

(z.B. inferiorer Frontalkortex [IFC]) während des Verstehens der verschiedenen Satztypen untersucht werden. Patienten mit Schizophrenie zeigten eine verringerte Leistung und Bearbeitungsgeschwindigkeit in der Sinn-Einschätzungsaufgabe unabhängig vom dargebotenen Satztyp. Darüber hinaus ergaben sich bei den Patienten Veränderungen in sowohl neuronalen (EKPs) als auch kortiko-hämodynamischen (z.B. IFC-Aktivierung) Korrelaten der Satzverarbeitung. Während neuronale und hämodynamische Marker in der Gruppe der Kontrollpersonen zum Teil stark korreliert waren, zeigte sich kein solcher Zusammenhang in der Gruppe der Schizophrenie-Patienten. Demnach können kombinierte fNIRS-EEG-Messungen auch Aufschluss über mögliche Zusammenhänge (bzw. deren pathologische Veränderung) verschiedener Bildgebungs-Parameter geben, die direkt (z.B. EKPs) versus indirekt (z.B. BOLD Kontrast) mit neuronaler Aktivierung assoziiert sind.

Einfluss von Stimmung und Trinkverhalten auf neurophysiologische Korrelate der Handlungsüberwachung: Die error-related negativity (ERN/Ne) bei starken und schwachen sozialen Trinkern A.-C. Ehli, M.-D. Hoang, S. Schneider, M. Nutzhorn, A. Krocze, A. J. Fallgatter *Universitätsklinikum Tübingen, Klinik für Psychiatrie und Psychotherapie, Tübingen* Chronischer Alkoholabusus geht mit einer Vielzahl neurobiologischer Auffälligkeiten einher, die sowohl Ursache als auch Folge der Abhängigkeitserkrankung sein könnten. Insbesondere Veränderungen im Entscheidungsverhalten sowie der Überwachung eigener Handlungen wurden wiederholt als zumindest aufrechterhaltende Faktoren diskutiert. Um entsprechende funktionelle Veränderungen weiter zu untersuchen, haben wir in zwei Studien neurophysiologische Korrelate der Handlungs-

überwachung (error-related negativity, ERN/Ne; error positivity, Pe) in Gruppen sozialer Vieltrinker – als Risikopopulation für die Entwicklung einer Alkoholabhängigkeit – untersucht und mit den entsprechenden Potentialen sozialer Wenigtrinker verglichen. Dabei kamen modifizierte Eriksen Flanker Tasks zum Einsatz, in denen Getränkebilder (alkoholisch vs. nicht-alkoholisch) zusätzlich zu den Flanker-Reizen dargeboten wurden. Es zeigten sich zahlreiche Gruppenunterschiede in ereigniskorrelierten Potentialen nach Alkohol-Cues, Flankerreizen und fehlerhaften Antworten. Unter anderem fielen reduzierte P300-Amplituden auf Flankerreize nach Alkohol-Cues insbesondere in der Gruppe der sozialen Vieltrinker auf. Daneben zeigten sich in dieser Gruppe – entgegen unserer ursprünglichen Hypothese – erhöhte Amplituden der ERN/Ne wie auch der Pe. Die Amplituden beider Potentiale waren außerdem signifikant mit den Werten im AUDIT korreliert, einem Fragebogen zur Erfassung von Merkmalen des Trinkverhaltens. In einer Nachfolgestudie wurden zudem Stimmungseinflüsse auf Cue-Reaktivität und Handlungsüberwachung bei sozialen Viel- und Wenigtrinkern untersucht. Hierbei erfolgte vor Beginn des Experiments eine Stimmungsinduktion über traurige vs. fröhliche Filmclips. Die Ergebnisse weisen auf Veränderungen in der Stimulusverarbeitung sowie im Reaktionsverhalten und entsprechenden Kontrollmechanismen bei sozialen Vieltrinkern hin, die teilweise im Sinne von stichprobenabhängigen Kompensationsprozessen interpretiert werden. Zudem erfolgt eine Einordnung der Befunde in aktuelle neurobiologische Modelle von Sucht und Abhängigkeit.

Transkranielle Gleichstromstimulation über dem linken dorsolateralen präfrontalen Kortex moduliert die auditorische Mismatch

Negativität, aber nicht die P3a und P3b

M. Weigl, A. Mecklinger, T. Rosburg *Department of Psychology, Experimental Neuropsychology Unit, Saarland University, Saarbrücken*

Transcranial direct current stimulation (tDCS) is a method which influences cortical excitability and behavior via constant low current applied to the scalp surface. Anodal tDCS typically increases cortical excitability, whereas the effect of cathodal tDCS is less clear. In the current event-related potential (ERP) study, we explored whether anodal and cathodal tDCS over the left dorsolateral prefrontal cortex (DLPFC) had an impact on attention (as indexed by the P3a to novels and P3b to targets in an active oddball task), acoustic stimulus discrimination (as indexed by the mismatch negativity, MMN, for duration, intensity, and frequency deviants), and resting state brain activity in a pre-post design. Resting state activity was affected only after cathodal stimulation, with increased levels of frontal theta activity in the post-tDCS measurement, as compared to sham tDCS. Analysis of the ERP data revealed that both P3a and P3b amplitudes decreased from the pre- to post-tDCS measurement, but this decrease did not vary between active and sham tDCS protocols. The MMN amplitudes for all kinds of deviants decreased over time, as well. For duration and intensity deviants, this reduction from the pre- to post-tDCS measurement was further modulated by tDCS. Compared to sham stimulation, anodal tDCS was associated with significantly stronger MMN reductions. No such modulation was found for the MMN to frequency deviants. These results complement previous findings that showed a reduction of the MMN to frequency deviants after anodal tDCS over the right DLPFC but no such reduction for the MMN to duration

deviants. Our findings shed further light on how frontal brain regions contribute to the generation of the MMN.

Prä-Feedback ERPs und Lernprozesse

A. Klein, W. Skrandies *Physiologisches Institut, Justus-Liebig-Universität Gießen* In a learning experiment comprising two phases, subjects were asked to assess whether given random numbers of at most four digits were divisible by a random divisor chosen from 2, 3, 5, 9 and 11, and were given auditory feedback upon answering. In the first phase, the subjects had to do 10 blocks of 20 tasks each, and were naïve with respect to strategies for solving the tasks, except for certain rules they might remember from school, where the rules for divisibility by at least 2, 3, and 5 (easy tasks) are part of the standard curriculum. All subjects stated that they did not know any rules regarding divisibility by 9 and 11 (difficult tasks), which is also reflected by the different rate of errors at both levels of difficulty. For the second phase of the experiment, an explicit rule for each of the divisors was explained to the subjects, and they had to do 10 blocks of 20 tasks again. The number of correct answers to difficult problems increased significantly as a result of learning, while the time needed to complete the tasks decreased significantly, and even *before* the auditory feedback, a systematic difference between the EEGs for correct and incorrect answers could be detected by means of a topographic analysis of variance. The effect of learning was reflected in a significant interaction of difficulty and phase, hence, our data show that the subjects show different electrical brain activity even before receiving feedback. We present these results as an addition to those presented at the previous DMM, where effects

occurring immediately after presenting every task were considered.

Learning to self-regulate slow cortical potentials in children with ADHD (Poster)

P. Aggensteiner, D. Brandeis, U. Strehl, M. Holtmann, FEEDBACK consortium *Central Institute of Mental Health, Department of Child and Youth Psychiatry, Mannheim*

Neurofeedback is a nonpharmacological treatment targeting neurophysiological deviations in children with ADHD. Slow cortical potentials (SCP) feedback training aims at voluntary control of the amplitude and polarity of the slow brain electrical activity related to attentional regulation. Despite considerable evidence for positive behavioral outcomes, only few studies reported on regulation performance outcome of SCP neurofeedback. Here, preliminary regulation outcomes of a multicentric randomized controlled clinical trial (ISRCTN761871859) are presented. ADHD children ($n=144$, age 8-12y) were assigned randomly to SCP-neurofeedback or electromyogram (EMG) feedback. Both feedback interventions consisted of 25 training sessions. The SCP-neurofeedback group had to gain voluntary control over slow EEG activity at Cz, while the EMG-feedback control group had to regulate electromyographic activity of left and right sided musculus supraspinati. Each training session consisted of three runs with visual feedback and one run without feedback (transfer condition). Performance of SCP self-regulation was computed from the SCP amplitude (average shift between 4-8s, mean over runs assessing differentiation between polarities, regression over sessions assessing learning, separately for positive/negative shift trials and feedback/transfer) and compared between groups using complete data from 60 neurofeedback and 57 EMG participants. Repeated-measures ANOVA

of their feedback SCPs showed a significant interaction between shift direction (trial polarity or side) and group, $F(1, 111)=24.576$, $p=.000$, $\eta=.181$. Only the SCP-feedback group differentiated between the polarities, achieving negative mean amplitudes in negativity trials and positive amplitudes in positivity trials. Only 40% of the SCP group also improved self-regulation during SCP training ("learning"). This subgroup significantly increased their negative shifts, but also showed less negative shifts at training start. These findings may be interpreted in terms of room for improvement, suggesting that initial capacity to differentiate between the two brain states limits the ability to further enhance self-regulation capabilities.

Announcements — Ankündigungen

- **BaCI 2015 - NFSI 2015 - ISBET 2015**

International Conference on Basic and Clinical Multimodal Imaging
International Symposium on Noninvasive Functional Source Imaging
International Society for Brain Electromagnetic Topography

Dates: September 1 – 5, 2015

Venue: Utrecht, The Netherlands

URL: <http://www.baci-conference.com/>

- **Annual Conference of ECNS, ISNIP & ISBET**

Joint Conference of EEG and Clinical Neuroscience Society (ECNS), International Society for Neuroimaging in Psychiatry (ISNIP) & International Society for Brain Electromagnetic Topography (ISBET)

Dates: September 9 – 13, 2015

Venue: Munich, Germany

URL: <http://www.eeg-munich.com/>

- **24. Deutsches EEG/EP Mapping Meeting / 24th German EEG/EP Mapping Meeting**

Conference language is German; English contributions will be accepted.

- **Schwerpunkte**

- Th. Fehr (Bremen), Komplexe Kognitionen und das inverse Problem der Neurowissenschaften — individuelle mentale Strategien machen das Gedankenlesen unmöglich (Übersichtsvortrag).
- M. Plichta (Mannheim), Koregistrierung von NIRS und klassischen psychophysiologischen Messmethoden (Symposium).

Sprecher:

Michela Balconi (Milan, Italy), Fabrice Wallois (Amiens, France), Ling-Chia Chen (Oldenburg), Martin Herrmann (Würzburg), Ann-Christine Ehlis (Tübingen), Günther Bauernfeind (Graz, Österreich), Joëlle Witmer (Bern, Schweiz)

- M. Doppelmayr F. Steinberg (Mainz), Gehirnaktivität bei Sport und Bewegung (Symposium).

- **Datum: 23. bis 25. Oktober 2015; Schloss Rauischholzhausen**

- **Information und Anmeldung unter: <http://www.med.uni-giessen.de/physio/>**

- **IOP World Congress**

18th World Congress of Psychophysiology (IOP2016)

Official World Congress of the International Organization of Psychophysiology (IOP)

Dates: August 31 – September 4, 2016

Venue: Melia Habana Hotel, Havana, Cuba

Chair: Pedro A. Valdes-Sosa

URL: <http://iop2016.cneuro.cu/>